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SURFACE WATER SITE INVENTORY OF THE POPLAR RIVER DRAINAGE AND PRELIMINARY CONSIDERATIONS OF POTENTIAL WATER QUALITY IMPACTS FROM THE COAL-FIRED, POWER GENERATION DEVELOPMENT NEAR CORONACH, SASKATCHEWAN

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SURFACE WATER SITE INVENTORY OF THE POPLAR RIVER DRAINAGE AND PRELIMINARY CONSIDERATIONS OF POTENTIAL WATER QUALITY IMPACTS FROM THE COAL-FIRED, POWER GENERATION DEVELOPMENT NEAR CORONACH, SASKATCHEWAN

Duane A. Klarich

INTRODUCTION

The Poplar River drainage in northeastern Montana is best characterized as a rural, dryland-agricultural region having a relatively sparse population. Due to the general absence of large municipalities and industrial activity, little attention has been given to this drainage in past years in relation to its water quality and biological features since point sources of pollution are practically negligible in the area (11). However, with the advent of a coal-fired, electrical generation proposal for the basin near Coronach, Saskatchewan, the Poplar area has undergone a hubbub of scientific activity and popular concern in recent years as a result of the potential land and water use impacts that might be associated with this development, and such activities are occurring on both sides of the international boundary.

The Saskatchewan Power Corporation is now in the process of constructing a 300-megawatt, electrical generating station which is scheduled to go on line prior to 1980. Their proposal indicates that this facility could be expanded to two and possibly four units sometime after this date (60). These stations will be located about 23 miles (37 kilometers) north of Scobey, Montana, and about eight miles (13 kilometers) north of the Canadian-United States border. Coal that is mined in the Coronach vicinity will be burned in these power plants, and the water that is required for their flow-through cooling systems will be obtained from a reservoir that is located on the East Poplar River near the generation site (60). The construction of the dam for this impoundment has been completed, and the reservoir is now filled with East Poplar waters. Significant evaporative losses are projected for these various facilities (43), both natural and induced, and as a result, significant increases in dissolved solids and other constituent concentrations are expected to occur in the reservoir and outfall and in the East Poplar River. Such increases could, in turn, affect downstream sites in Montana, and this forms one of the more obvious impacts associated with the Coronach development. Other major impacts could include, for example, the introduction of toxic and harmful substances into the stream via fly-ash and bottom-ash slurries and from anti-corrosive, additive substances, the disruption of important aquifers during the mining phase, and the general degradation of air quality in the basin via the introduction of materials in wind-borne, stack effluents.

The recognition of these potential impacts plus the elucidation of other possible problems have aroused the ire of a variety of special interest groups and other concerned parties within and without the basin. This would include the agriculturists in the region who feel that their livelihoods might be threatened by the probable degradations of air and water quality associated with their farms. In addition, urban dwellers in the drainage have expressed concern over the possibility that impacts might be felt in their municipal supplies which are typically obtained from shallow, alluvial wells (26). Another source of antagonism to the Coronach development comes from the environ-

mental interests who believe that the power facilities could degrade the aquatic ecosystems of the drainage via water quantity and quality alterations. All of these concerns are justified, at least at the present time, and the environmental concern is intensified by the fact that the Poplar River affords, what appears to be, a well-balanced, warm water system that now supports a viable and healthy sport fishery. As stated by Needham (1976), although " . . . Montana contains many prairie streams, few provide a sport fishery. While habitat in the Poplar River is of sufficient quality to maintain a sport fishery, only a small difference in habitat separates this river from numerous other streams which support only non-game species." Thus, the Montana Department of Fish and Game has expressed concern that water quantity reductions (49) and quality degradations might eliminate this valuable recreational resource; and this points to the question of whether or not some energies should be expended towards preserving this somewhat unique prairie stream in its present state.

In addition to the Montana Department of Fish and Game, numerous other agencies and associations on the local, Indian tribal, state or provincial, regional, legislative, and federal levels have become embroiled in the Coronach-Poplar question. In addition, since the Poplar is a transboundary river, various international entities such as the United States Department of State and the International Joint Commission have become involved in assessing the Coronach development. Thus, many interesting debates are yet to come, and the Poplar drainage can no longer be viewed as a relatively unknown and secure, serene and peaceful slice of the Northern Great Plains.

STUDY OBJECTIVES, APPROACH, AND RELATED INVESTIGATIONS

When concrete plans to begin construction on the Coronach power facility were first announced to the public, the Water Quality Bureau of the Montana Department of Health and Environmental Sciences obtained funding from the United States Environmental Protection Agency (Research Grant No. R008115) to initiate a water quality-related study in the Poplar drainage. In view of the potential impacts that might be drived from the Canadian development, and in view of the general lack of water quality and biological information for the

region, the objectives of this study were summarized as follows: "The proposed work will delineate present conditions, predict impacts of the proposed development, and provide a basis for determining how the impacts may be minimized (43)." The Water Quality Bureau started this study during the summer of 1975, but during the subsequent months, numerous other projects related to the Coronach development were initiated in the region by a variety of state and federal agencies. As examples, such studies would include the comprehensive water quality and quantity monitoring programs that were recently initiated in the drainage by the United States Geological Survey along with the water use determinations that have been completed by the Montana Department of Natural Resources and Conservation and the Fort Peck Tribes. In addition, fisheries surveys have been conducted by the Surveillance and Analysis Division of the Environmental Protection Agency and by the Fisheries Division of the Montana Department of Fish and Game, and an air quality monitoring program has been established in the basin by the State Air Quality Bureau. As a result of these various investigations, the objectives of this particular study have been modified, refined, and delimited to some extent from its original inception in order to avoid a duplication of effort between projects.

As a means of integrating these various investigations, the Environmental Protection Agency is now undertaking the preparation of an environmental impact statement for the Poplar River Basin, and the types of studies that will be ultimately involved in this effort, in addition to those noted above, can be summarized as follows (70): (1) meteorology (Montana Air Quality Bureau), (2) visibility (Montana Air Quality Bureau), (3) coal analyses (State of Montana), (4) soil analyses (Montana State University), (5) overburden leaching (Montana State University), (6) vegetation chemistry (Montana Air Quality Bureau), (7) furbearer impacts and benthic studies (Montana Department of Fish and Game), (8) groundwater studies (United States Geological Survey), (9) vegetation effects (Environmental Protection Agency), (10) thermal discharges (Environmental Protection Agency), and (11) land use mapping (Environmental Protection Agency). As a final point to this listing, the State Water Quality Bureau has obtained additional monies to conduct computer-based, water quality modeling exercises on the Poplar drainage in relation to the Coronach power generation facilities, and the initiation of this modeling project has also delimited the scope of this particular investigation.

With the advent of these many investigations, the focus of this study came to rest primarily upon the biological and quality characteristics of surface waters in the Poplar drainage; however, other features of the drainage such as its water use and surface hydrology will also be considered to some extent. The site inventory aspects of the investigation will be stressed in the study report, and in this regard, quality data from other agencies will be primarily utilized in this review since the sampling program initiated by the State Water Quality Bureau was largely curtailed in favor of the United States Geological Survey monitoring efforts in the region. Some consideration will also be given to the surface water impacts that might eventually emanate from the Coronach development, but for the most part, these considerations will be of a qualitative rather than a quantitative nature; it is assumed that the Bureau's modeling project will have the capacity to accurately describe these potential impacts in a quantitative sense.

Such qualitative considerations of surface water impacts will be made from

a parametric point of view which is a somewhat more specific approach than the case of viewing these impacts from an "impact-source" standpoint. Each of these approaches has certain advantages and disadvantages depending upon the type of development under consideration and its potential impacts, upon the data availability, and upon the theme of the study. The "parameter-based" application assumes that those water quality variables that are at critical levels in the natural environment, or very close to being at critical levels, are the ones that, after being affected by "impact-sources" of the development under consideration, will have the greatest post-development effects on the region. For this particular inventory, the "parameter-based" approach appeared to be the most amenable since the major impact that is projected for the Coronach development involves a concentration of dissolved constituents by the power plant facilities.

To initiate this "parameter-based" survey, the water uses in the Poplar drainage were first elucidated, and various literature sources were then reviewed to establish the types of water qualities that would be necessary for each particular use. From this literature review, critical water quality parameter concentrations were established for each water use, forming reference criteria, and these reference criteria can then be compared to the results of sample analyses from various locations in the Poplar drainage. In this manner, potential "problem" parameters can be identified, and this identification step is important to a water quality inventory since such "problem" variables will most likely have the highest probability for providing significant impacts subsequent to the initiation of any particular development. As a further step, the ratio of the parametric reference criteria to the typical concentration of this variable in a water may provide some idea into the level of variable increase that will be required in order for the parameter to curtail or further degrade a water use. Specific "impact-sources" from a development can then be reviewed, e.g., from the Coronach power facilities, and some judgements might then be made as to the likelihood of such post-development increases in variable concentrations. In terms of the Coronach facilities, the water quality modeling effort of the Water Quality Bureau might be able to provide the requisit quantification.

Based on the above discussion, the general objectives of this study and the associated study report, as revised from the original inception, can be stated as follows: to provide some degree of knowledge into the biological and water quality characteristics of surface waters in the Poplar River Basin and to point out those parameters that may be close to or at critical concentrations in the natural environment so that some insight might be gained into the possible impacts of the Coronach, coal-fired power generation facilities and into the possible water quality problems that may be facing the Poplar drainage within the next few years. It should be noted, however, that the final resolution of these impact considerations will be dependent to some degree upon the eventual decision of the International Joint Commission concerning the Poplar, transboundary apportionment recommendations that have been put forth by the Poplar River Task Force (53). It is hoped that this report will also provide some insight into the possible consequences of their decision.

For organizational purposes, the results obtained from this Water Quality Bureau study of the Poplar area will be divided into two segments. One report will deal primarily with the water quality characteristics of surface waters in the Poplar drainage in relation to the water uses of the region, but it will also consider the potential water quality impacts that might be associated with

the Coronach electrical generation development as described previously. This topic then provides the theme for this particular write-up. In addition, a second report, entitled "Biological Features of Surface Waters in the Poplar River Drainage of Montana", will be prepared as a supplement to this first effort. This second report will contain considerations of the Poplar fishery, periphyton communities, and macroinvertebrate populations along with estimates of primary production in the streams of the drainage. Water quality-biotic interrelationships will also be considered in this second report as will the possible effects of the Coronach development upon specific biotic features of the system. These two reports, therefore, should provide a fairly comprehensive description of the aquatic ecosystems of the region and of the potential impacts that might be affecting this basin within the next few years.

GENERAL DESCRIPTION OF PERTINENT FEATURES IN THE STUDY AREA

GEOGRAPHY

The Poplar River drainage, having the 40Q sub-basin designation of the United States Geological Survey (71), is located north of the Missouri River in the northeastern corner of Montana with its headwaters in the extreme southern and middle portions of Saskatchewan, Canada. In Montana, the northern portions of the sub-basin fall primarily into Daniels County, while its southern portions fall into Roosevelt County. A small northwestern segment of the region is located in Valley County. The drainages of numerous small streams and Missouri tributaries lie to the west of the Poplar sub-basin (e.g., Tule, Wolf, Little Porcupine, and Porcupine Creeks), and the Big Muddy Creek drainage lies to the east. As a result, the Poplar River, along with the Milk River, is a major tributary to the Missouri River east of Fort Peck Reservoir. The Poplar joins the Missouri near Poplar, Montana about 55 miles (89 kilometers) west of the Montana-North Dakota border. The Poplar drainage is a part of the Lower Missouri River Basin, as defined by the State Water Quality Bureau for water quality management planning purposes (11), and along with the lower portions of the Yellowstone River drainage, it is a part of the Two Rivers Region in northeastern Montana that has been designated by the Montana Environmental Quality Council for the purposes of a statewide, environmental review (45). In

a broader sense, however, the Poplar River is a portion of the upper Missouri River system (68).

The Poplar River originates as three forks in the Wood Mountain region of Saskatchewan, and each fork separately crosses the United States-Canadian border to join at two locations within Montana (Figure 1). The Coronach development will be located on the East Fork or East Poplar River, and this stream and the Middle Fork of the Poplar River join near Scobey, Montana about 12 miles (19 kilometers) below the international boundary. The West Fork joins the Poplar mainstem about 25 miles (40 kilometers) further downstream. A major portion of the West Fork drainage is found in Montana with a drainage area of 145 square miles at the border versus a total area of 1010 square miles at its mouth (55). In contrast, the Middle and East Forks have a major portion of their drainages in Canada with areas of 358 and 542 square miles at the international boundary, respectively, versus total areas of 582 and 749 square miles at points near Scobey (55). The total drainage area of the Poplar Basin equals about 3330 square miles.

These three forks of the Poplar mainstem and their points of confluence divide the Poplar system into five segments--three upper reaches consisting of the three forks, a middle reach of the mainstem between the confluences of the forks (a 25 mile segment), and a lower reach of the mainstem below the confluence of the West Fork to its mouth near Poplar (a 40 mile segment). Discussions of the Poplar River drainage will be generally organized on the basis of these same subdivisional lines. In addition to the three major forks, other tributaries of some import to the Poplar region would include Girard, Coal, and Cow Creeks and the East Tributary of the West Fork, all located near the international boundary, and Butte, Police, Cottonwood, and Hay Creeks located entirely within Montana. For the most part, however, these smaller streams will not be given extensive considerations in this review with attention riveted primarily on the two reaches of the Poplar mainstem and the three major forks of this river.

GEOLOGY AND SOILS

The Poplar River Basin is characterized by a continental type of climate with cold and dry winters (typically between 12°F and 33°F with about 1.2 inches of precipitation occurring primarily in the form of snow), with moderately warm and wet springs (typically between 28°F and 63°F with about 5.7 inches of moisture falling as gentle rains), and with somewhat warmer and drier summers (typically between 49°F and 73°F with about 4.7 inches of precipitation) (11). The soils of the region consist of alterations in alluvium, till, and other geological materials that have been affected by varying conditions of climate, topography, and living organisms (75). However, the major factors influencing the basin's soils are related to the complicated geological history of the area, and many of its dominant land forms were derived from extensive periods of sedimentation, regional uplift, erosion, and glaciation.

During the Pleistocene epoch (0.02 to one million years ago), most of the basin was covered by a large continental ice sheet that blocked the Missouri River and its tributaries and created numerous glacial lakes (11). Due to the advancement and ultimate recession of this continental ice sheet, Pleistocene glacial deposits cover much of the basin, and most of the region's soils are underlain by glacial tills which are the heterogeneous and nonsorted-unstrati-

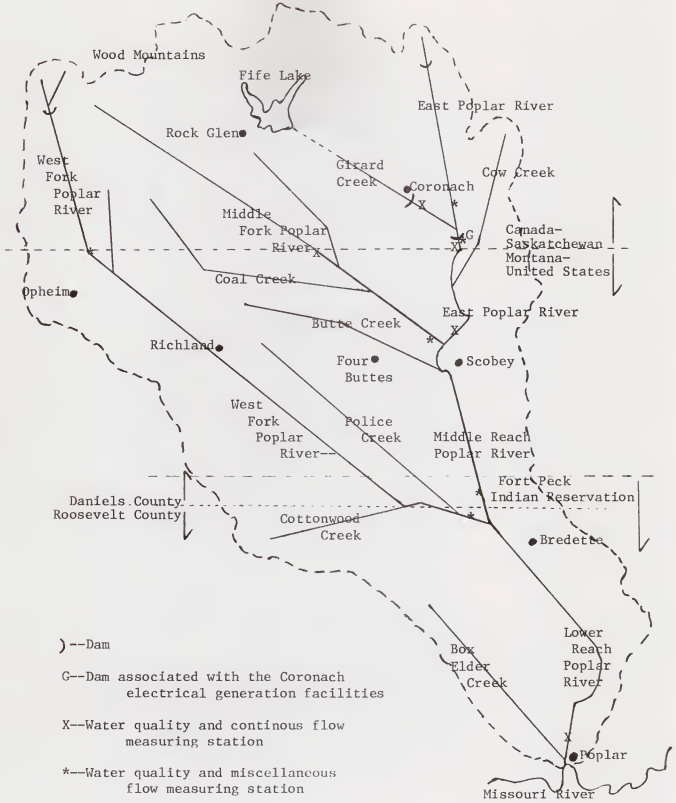

Figure 1. Schematic diagram of major streams and pertinent features in the Poplar River drainage.

fied, compacted mixtures of clay, silt, sand, gravel, and boulders that were carried and eventually dropped by these glaciers. Finer materials such as silt and clay were generally deposited in the glacial lakes, and coarser materials such as sand and gravel were deposited in the outwash channels of the glaciers (11). Subsequent to the retreat of the ice sheet, an extensive drainage and sedimentation of the region over a period of time has resulted in the filling of many stream valleys with Recent alluvial deposits which are composed chiefly of silt, clay, and sand with local lenses of gravel. With the occurrence of geologic faulting in the basin, bedrock formations are exposed at various points through the drainage, and these are of a sedimentary origin, marine and non-marine, ranging in age from Upper Cretaceous (70 to 100 million years old) to early Tertiary (50 to 70 million years old) (11). As a result of these various historical features, the soils in the Poplar River Basin are found to be quite varied in character, and they demonstrate a wide range of suitability to agricultural use.

The best agricultural soils in the Poplar drainage are the well drained soils located on the nearly level to strongly sloping and undulating glacial till uplands (11, 75). Some of these soils are deep and dark colored with loam or clay loam surfaces on a clay loam subsoil. Other of the soils are more light colored, shallow, and calcareous in nature with clay or clay loam surfaces over partly weathered glacial till. These upland soils present a moderate erosion hazard only under improper management practices. Another type of good agricultural soil on the undulating upland areas are the well drained and deep soils having dark colored sandy loam and loam surface layers with a sandy clay loam subsoil over loose sands and gravel. However, these soils can present a wind erosion hazard if the land is left fallow for extended periods of time (11). On the shale uplands, well drained, deep soils with dark colored, silt loam surface layers and silty clay loam subsoils are found underlain by silty shale, although light colored, shallow, and calcareous soils are also found in these same areas (75). The shale layer is usually encountered within 20 to 40 inches of the surface. These soils also have some agricultural value, and they are commonly used for farming and grazing; but this shaley type of soil can afford a moderate erosion hazard (11).

On the gently sloping fans and terraces, well drained, moderately deep or deep, and dark colored soils are found with loam to silty clay and sandy loam surface layers and with clay loam, silty clay, and sandy clay loam subsurfaces over loose sand and gravel or loose sands (75). Two types of soils are found on the nearly level uplands--the well drained, dark colored, and deep soils having loamy surface layers and sandy clay loam and clay loam subsoils, and the calcareous, shallow, clay loam soils over partially weathered clay loam glacial till. Some of the more well drained of these fan-terrace and level upland soils are used for dryland farming; however, clay loams with moderate salinity have developed in these soils on poorly drained areas, and this feature detracts from their agricultural value. These soils generally have a moderate erosion hazard (11).

Relatively poor agricultural soils are located on the very steep and dissected uplands of the Poplar drainage. These regions have well drained, light colored and typically shallow, silty-gravelly-clayey soils overlying silty shales, gravels, or glacial tills (75). On the very steep slopes of rough lands called "breaks", well drained, shallow, calcareous soils of a silt loam or clay loam character are found underlain by silty shale or clay loam glacial

till and barren shale outcrops (11). These types of soils commonly present a severe erosion hazard, as evidenced by the topography of the "breaks" and the dissected upland areas, and such soils are generally not farmed for this reason.

Another relatively poor type of agricultural soil is located on the flood plains of the Poplar Basin. These plains are dominated by poorly drained, deep and calcareous soils with silt loam to clay surfaces and subsoils with varying degrees of subsoil stratification, wetness, and surface salinity (75). This type of soil can also be found on some of the fans and terraces in the region. Since many of these soils can present a high erosion hazard, most of these lands are not under cultivation except for those that have the lighter textured loams which are watered by irrigation (11). In addition, areas of deep and poorly drained clay soils occur on the flood plains in conjunction with the lake deposited sediments. These soils also have a high erosion hazard, and drainage is generally too slow to allow for successful dryland agriculture. In conjunction with these poorly drained and clayey soils of the flood plains, poor farm lands are also commonly associated with the excessively drained, sandy and silty loam soils that can be found in the lower portions of the Poplar Basin. These sandy soils are located on hilly and stabilized sand dunes, on the very steep and rough, broken edges of the glacial till plains and outwash plateaus, and on the silty shale bedrock that is often associated with the glacial till plains (75). These soils also have a relatively low agricultural value, but for different reasons than those intimated for the flood plains.

Of the various types of soils described above, only four soil series, as described by the Soil Conservation Service, are associated with irrigated lands in the Poplar River drainage of Montana--Haverlon, Lohler, Glendive, and Banks (36). The properties of these irrigated soil series, as obtained from official descriptions, are summarized in Table 1. Of these soils, the Lohler series will present the most problems to irrigation in relation to its fine textural, montmorillonitic, and slow to moderate permeability characteristics. Unfortunately, the Lohler series is one of the most common soils in the region, and careful agricultural management practices have to be directed to those lands dominated by this soil series in order to avoid surface degradations. Those practices that are successfully applied to the Lohler soils should also be adequate for the remaining soil series in view of their better irrigational properties (36). None of these four series have been described as appreciably salty, so the presence of soil salinity would indicate that the current management practices of the area are questionable in relation to the water quality characteristics of the Poplar River. In conjunction with the future soil analyses that are to be conducted in the Poplar Basin, this feature can be used as a diagnostic tool for judging the suitability of current land use practices. If deteriorations in soil quality are shown, this will be suggestive of the need for a different management direction in relation to the irrigated soils, particularly in view of potential stream salinity impacts that might be derived from the Coronach development.

LAND USE

The Poplar River Basin is a sparsely populated, generally rural, and slow growing region that is largely dominated by agricultural pursuits. Daniels and Roosevelt Counties, which comprise the major portion of the Poplar drainage (71), had a combined population of 13,448 (65) and a population density of 3.6 individuals per square mile in 1970 that demonstrated only a 3.5% increase in num-

Table 1. Properties of irrigated soil series in the Poplar River Basin of Montana. Data taken from Klages (1976).

Soil Property	Soil Series			
	Banks	Glendive	Haverlon	Lohler
Relative Importance Ranking	Fourth	Third	First	Second
Textural Family	Sandy	Coarse Loamy	Fine Loamy	Fine
Minerology	Mixed	Mixed	Mixed	Montmorillonitic
Available Water Capacity to Four Feet	3.8"	Unknown	8.8"	7.4"
Relative Permeability	Rapid	Moderate to Moderately Rapid	Moderate	Slow to Moderate
Permeability in inches per hour	2.0 to 20, over 6.0 to 20	Unknown	0.6 to 2.0	0.06 to 0.6
Shrink-Swell Features	Low	Unknown	Moderate	High

bers from 1960 (75). Like many rural areas, the counties' population showed a higher proportion of males than females during this same year, about 51.3% and 48.7% respectively. In contrast, the population growth of Montana as whole, estimated at about 9.6% (6), was considerably greater than that for Daniels and Roosevelt Counties, and the more urbanized areas of the State, such as Silver Bow County, demonstrated a much higher population density than the two Poplar counties, on the order of 60 individuals per square mile, with a closer equivalence of males and females, e.g., 49.1% and 50.8% (females) in Silver Bow County (1960) (76). Of the males and females residing in Daniels and Roosevelt Counties, only 26% are found in what might be classified as urban areas with 22% of the people dwelling in intermediately-sized communities having populations of about 1700. A major proportion of the residents, about 53%, are situated in generally rural settings, either on farms, in outlying city areas, or in small towns with populations of less than 1000 people (75).

The pastoral proclivity of the Poplar region is also illustrated by the employment information in Table 2 which shows that about 41.4% of the employed people residing in Daniels and Roosevelt Counties were recently engaged in agricultural or governmental pursuits in contrast to averages of 23% for Montana and 24% for the United States (64). In contrast, only 11.4% of the people in the two counties were involved with manufacturing, construction, and mining endeavors in relation to averages of 20% and 33% for Montana and the nation as a whole. Agricultural support activities--transportation and utilities, trade, and services and finance--accounted for about 47.3% of the people's activities in the basin versus average values of 56% and 42% in Montana and the United States respectively. This agricultural nature of the Poplar region can be further illustrated by various land use statistics (Table 3) wherein 98.4% of the lands in the two major counties of the Poplar Basin were devoted to farms and ranches with the remaining portion devoted to miscellaneous uses such as forests (0.4%), urban and built-up areas (0.7%), small water areas (0.1%), and unusable, e.g., rock outcrops (0.4%) (11). About 36% of the lands in the two county area were owned by private interests, while 24% were associated with the Fort Peck Indian Reservation; about 40% of the lands in the region were controlled by various state and federal entities (75).

As indicated in Table 3, croplands accounted for the greatest percentage of land use in the Poplar region with 75% of the farms devoted to the raising of cash grain crops in 1964 (75). In turn, 14% of the agricultural operations in the two county area were devoted to the raising of livestock, although only 0.5% of the farms were devoted to poultry or dairy; approximately 10% were involved in general and miscellaneous agricultural activities. About 72% of the total cash receipts in the Poplar region were derived from crops with cash receipts from both crops and livestock totalling 21.6 million dollars for the two county area in 1967 (75). Less than one percent of the acreage in the basin was devoted to the irrigation of hay and pasture grasses via spreader dikes or gravity-pump diversion (54), although approximately 20% of the land in the Lower Missouri River Basin of Montana is purported to be irrigable (11). This indicates that the Poplar drainage is primarily a dryland farming region at the present time with grains representing the major agricultural product or cash commodity of the area and with cattle and the related forage crops representing a secondary source of agricultural income to the basin.

Table 2. Percent employment in the Poplar River drainage (Daniels and Roosevelt Counties), Montana, and the United States by industry group (1960). Data were taken from the United States Bureau of Census (1960).

Industry	Poplar Drainage	Montana	United States
Agriculture	35.6	17	11
Construction	6.1	7	5
Forestry and Fisheries	0.0	1	1
Government	5.8	6	13
Manufacturing	3.6	10	27
Mining	1.7	3	1
Trade	17.4	21	19
Transportation and Utilities	6.3	9	7
Services and Finance	23.6	26	16
Total	100.1%	100%	100%

Table 3. Land use characteristics of the Poplar River drainage in 1967 (Daniels and Roosevelt Counties) expressed in acres as the percent of the total. Data were taken from the United States Department of Agriculture (1970).

County	Total Inventory	Cropland	Pasture	Range	Forest	Other
Daniels	911,938	543,166	4,550	352,896	0	11,326
	100%	59.6%	0.5%	38.7%	0.0%	1.2%
Roosevelt	1,501,677	731,915	20,090	722,902	8,745	18,025
	100%	48.74%	1.34%	48.14%	0.58%	1.20%
Total	2,413,615	1,275,081	24,640	1,075,798	8,745	29,351
	100%	52.8%	1.0%	44.6%	0.4%	1.2%

WATER USE

On February 21, 1975, the Saskatchewan Department of the Environment granted license to the Saskatchewan Power Corporation to commence with the construction of the proposed electrical generation facilities, power plant and dam, near Coronach, Canada. Since this power development will consume significant quantities of water, the International Joint Commission (IJC), which was established by treaty circa 1910 to mitigate transboundary water disputes between the United States and Canada, thereby " . . . instructed the International Souris-Red Rivers Engineering Board to proceed with investigations leading to recommendations on equitable apportionment of the waters of the Poplar River Basin (53)." To do so, this Engineering Board, with the approval of the IJC, appointed an international Poplar River Task Force (PRTF). The PRTF was instructed to develop apportionment alternatives and to recommend that alternative that would appear to be the most amenable to all of the concerned parties. In addition, the PRTF requested that the Department of Regional Economic Expansion in Canada and the Water Resources Division of the United States Geological Survey carry out " . . . a study of the natural flow of the Poplar River at selected points in Canada and the United States (55)." The PRTF also asked the Saskatchewan Department of the Environment and the Montana Department of Natural Resources and Conservation (DNRC) to carry out studies " . . . to determine the existing (1975) and historical (1931-1974) surface-water use in the Poplar River Basin in Saskatchewan and Montana (54)." Furthermore, investigations of the "probable future water use" in the basin were also undertaken by these same provincial-state agencies (56). As a result of these efforts, an apportionment recommendation has been recently developed by the PRTF and submitted to the IJC via the International Souris-Red Rivers Engineering Board (53), and the associated natural flow and water use studies have also been completed with the corresponding reports available as of January-February, 1976 (54, 55, 56). The results of the water use study conducted by DNRC and its Saskatchewan counterpart describing the current status of water use in the Poplar drainage are summarized in Table 4.

None of the communities in the study region obtain their municipal supplies directly from the Poplar River. Most of these waters are obtained from shallow groundwater sources, and many of the wells are located in the alluvium along the streams of the drainage. As an example, the community of Scobey is served by three wells, forty feet deep, that are drilled into the alluvium of the Poplar River below the confluence of the East and Middle Forks (26). Water use at Scobey from this source amounted to about 340 acre feet for fiscal year 1973-1974 with an added 55.8 million gallons metered for other uses (26). The village of Coronach also obtains its water from a shallow well that is associated with the East Poplar River (54). The waters in these shallow, alluvial aquifers are probably recharged by the surface waters in streams of the region since the " . . . low gradient of the river, the meandering characteristic of the rivers (except part of the East Poplar), and the high water table in the alluvium indicate the usual close interrelationship between surface-water and ground-water systems (26)." As a result of this relationship, DNRC has listed the basin's municipal consumption as a component of the total surface water use of the region. As indicated in Table 4, however, this municipal use represents only a small percentage of the total, i.e., about 3.7% in 1975, and municipal use in the Poplar Basin is expected to increase by only about 230 acre feet per year (AF/Y) by the year 1985 (56).

Table 4. Existing water use (1°75) in the Poplar River Basin in acre feet per year (AF/Y) with the number of projects for each category presented in parenthesis. Data were taken from the Poplar River Task Force (1976b).

Drainage	Domestic Use	Domestic Evap(b)	Irrigation Sprin-Grav(a) Acres	Irrigation Sprin-Grav(a) AF/Y	Irrigation Back Flood(a) Acres	Irrigation Back Flood(a) AF/Y	Municipal	Subtotals AF/Y	Drainage TOTALS AF/Y
Canada:									
East Poplar River(c)	103(121)	663	--	44(6)	--	178(25)	36(1)	1024(153)	--
Middle Fork Poplar River(d)	53(40)	83	--	10(1)	--	42(2)	--	188(43)	--
West Fork Poplar River(e)	24(20)	252	--	5(1)	--	20(4)	--	301(25)	--
Other tributaries	2(3)	24	--	--	--	20(1)	--	46(4)	46(4)
Subtotals	182(184)	1022	--	59(8)	--	260(32)	36(1)	1559(225)	--
Montana:			Grav-Pump**		Spreader Dikes				
East Poplar River(f)	39(25)	45	65	100(3)	530	441(4)	0(0)	625(32)	1649(185)
Middle Fork Poplar River(g)	88(52)	55	1269	1950(6)	484	403(4)	0(0)	2496(62)	2684(105)
West Fork Poplar River(h)	320(234)	275	389	598(4)	474	396(7)	0(0)	1589(245)	1890(270)
Middle reach Poplar River(i)	155(109)	233	1363	2095(16)	364	303(6)	350(1)	3136(132)	--
Lower reach Poplar River(j)	178(190)	444	56	86(6)	235	196(5)	0(0)	904(201)	4040(333)*
Subtotals	780(610)	1052	3142	4829(35)	2087	1739(26)	350(1)	8750(672)	--
TOTALS	962(794)	2074	--	4888(43)	--	1999(58)	386(2)	10,309(897)	10,309(897)

(a) Sprinkler or gravity, estimated as use plus evaporation with 0.8 of the projects having back flooding; (b) includes the mean evaporation (evap) of large reservoirs; (c) East Poplar plus Fife Lake and Cow and Girard Creeks; (d) Middle Poplar plus Coal Creek; (e) West Poplar plus its East Tributary; (f) East Poplar plus Cow Creek; (g) Middle Poplar plus Woodley and Coal Creeks; (h) West Poplar plus Police and Cottonwood Creeks; (i) Poplar mainstem above the West Fork plus Butte Creek and Manternach Coulee; (j) Poplar mainstem below the West Fork plus Box Elder Creek; *middle reach plus the lower reach; **gravity and pumping.

Table 4 indicates that domestic applications, i.e., livestock water, household uses, garden irrigation, and stock pond evaporation (56), represent another minor use of surface water in the Poplar drainage at the present time in contrast to the demand that is imposed by irrigation. Although such domestic uses comprise about 29% of the total water use in the region, a major portion of this consumption is indirect in being related to reservoir evaporation (68%). This latter feature is especially notable in Canada as a result of the large reservoir evaporation data that was included with this listing (54). Domestic use in the basin is projected to increase by 555 AF/Y by 1985 whereas irrigation is expected to expand to at least 5000 AF/Y by this same year which excludes whatever developments might occur on the Fort Peck Indian Reservation (56). At the 1975 levels, irrigation accounted for about 67% of the total surface water use in the drainage with most of these diversions occurring within Montana. In the main, Saskatchewan is a relatively minor user of Poplar waters at present, but the Coronach development will greatly increase this Province's demands upon this river system in the very near future.

In keeping with the rural nature of the Poplar Basin, no major industrial users of water are now in operation within this drainage. But by 1979, industrial uses in Canada should equal 4,400 AF/Y through the advent of water losses by natural and forced evaporation and from in-plant consumptive uses as a result of the power generating facility and reservoir near Coronach, Saskatchewan (56). Increases to 6,400 AF/Y and 8,300 AF/Y are anticipated for 1982 and 1984 if two additional generation units come on line, and the industrial use of the basin's waters in Canada could be increased by an additional 1,940 AF/Y by 1986 if a fourth unit is put into operation (56). In the United States, 7000 AF/Y may be eventually required for the operation of a potash mine near Scobey, Montana. This mine could be developed by 1985 if solution mining is proved to be an economically feasible alternative for the Scobey area (56). Outside of these two mining and power generation developments, additional industrial uses of water are anticipated to be relatively minor for the Poplar Basin in the immediate future. "No other firm plans or intents have been identified by government or private industry related to the development of coal reserves in the area, and given the extensive lead times . . . , it would appear doubtful that any other large scale project would be commissioned by year 1985 (56)." Beyond 1985, however, additional developments related to coal would appear to be likely, both in the United States and Canada, and the occurrence of mineral deposits in the basin apart from coal, e.g., quartzite and bentonite, would also point to the likelihood of future industrial developments placing an added demand upon the water resources of the drainage.

In addition to the surface waters, groundwater provides another important, but largely undeveloped water resource in the Poplar drainage (75). Similar to the surface waters, groundwater is now widely used for stock water and for domestic purposes, and it is probably the most widely utilized source of water for these two uses in the Lower Missouri Basin (11). As noted, shallow alluvial aquifers are also used for municipal supply, and such shallow sources of groundwater are widely available in several of the geologic formations throughout the region. As of 1970, 1151 well and 220 spring appropriations were on file with the Montana Bureau of Mines and Geology for Daniels and Roosevelt Counties (75). Of these 1371 appropriations, 43.5% were made for livestock use while 18.1% were directed primarily to domestic purposes; 28.9% of the appropriations had listings for both of these water uses. In contrast, only 3.6% of the appropriations cited irrigation as a use, and this would indicate a re-

latively minor utilization of groundwater for this purpose relative to that used for livestock watering and in relation to the irrigation water that is derived from surface water resources (Table 4). Other minor appropriations of groundwater in the two counties would include public supply (1.2%) and general applications (1.2%) with the intent of 3.4% of the spring and well appropriations unknown. In addition, industrial uses of groundwater in the Poplar Basin are practically negligible at the present time, although some supplemental groundwater use is foreseen for the future in relation to the potash mining development near Scobey (54, 56).

In addition to the surface water uses described previously, i.e., irrigation, livestock watering, domestic, and municipal (Table 4), the PRTF also recognized the existence of the Poplar River fishery as an additional basin feature that requires quality waters for its successful conclusion (54). Some attention was also given to water quality matters, but these instream considerations were largely "postscriptual" in character (53, 54). The Task Force pointed to the marginal nature of the fishery in prairie streams such as the Poplar, and they indicated that basin " . . . developments which would reduce water quantity or quality could result in habitat changes which could be detrimental to desirable game fish species (54)." However, no attempt was made to quantify the minimum instream flows that will be required for the maintenance of a reasonable water quality and for the support of this prairie fishery. The PRTF cited two reasons for this exclusion: " . . . (1) such use is not consumptive and therefore is not a depletion of natural flow and, (2) minimum flows have not been established under law (54)." Nevertheless, as suggested by Needham (1975, 1976) and Aderhold (1975), some attention will have to be given to the quantification of these instream requirements if the Poplar fishery is to be maintained in a viable and resident form.

WATER POLLUTION PROBLEMS

Due to the lack of industrial development in the Poplar Basin, point sources of pollution reaching the Poplar River from this economic sector are so far largely absent from the drainage (11). This also applies to the domestic sources of pollution. Most of the smaller communities in the region are served by septic tank systems that appear to be functioning satisfactorily at the present time (33). Although septic tank drainfields can create groundwater pollution problems when in high densities or when closely associated with water supply systems, few problems of this kind have been identified for the Lower Missouri River Basin (11). The larger communities in the Poplar Basin, such as Scobey, are sewered with the municipal wastes directed to sewage stabilization ponds or lagoons for treatment. Groundwater can also be polluted by seepage from these lagoons, but this problem has not been reported for the drainage (11). In addition, surface discharges from such lagoons would represent point sources of pollution to the streams, but the lagoon system serving the town of Scobey rarely, if ever, discharges to the Poplar River (33) which would eliminate this community as a source of municipal pollution. The town of Poplar is also located in the Poplar Basin, but its lagoon discharges to the Missouri River which is located out of the Poplar study area. Thus, the streams of the Poplar drainage do not appear to be generally utilized for the conveyance of point source wastes; this feature might be viewed as an instream water use since it requires the presence of adequate, in situ water volumes for dilution purposes in order to avoid any violations of Montana's water quality standards.

In contrast to the point sources of pollution, non-point sources have a much greater potential for influencing the surface waters and groundwaters of sparsely populated, farming regions such as the Poplar River Basin than the more discrete wastewater inputs. Such non-point wastes often have an agricultural derivation, either directly or indirectly, and they would include irrigation return flows (salinity), animal wastes (coliforms and BOD), overland runoff and erosion from cultivated and rangelands (suspended sediment), and fertilized and otherwise treated agricultural areas (eutrophic factors and pesticides). However, the total and actual effects of these agricultural sources of pollution on the waters of the Poplar drainage are generally unknown at present, although some water quality degradations might be expected. As stated by Bloom and Botz (1975), agricultural " . . . pollution is transient in both time and space and is complex due to the variability of agricultural practices. The effect of agricultural wastes on water quality generally is difficult to determine without long-term studies. Gross agricultural pollution problems in the basin are not apparent; however, the summation effect of the many small agricultural abuses is felt to be significant." Such non-point sources of pollution can also be derived from non-agricultural activities, including runoff from uncultivated and ungrazed lands (e.g., erosion of the "breaks"), salinity from saline soils in the area (e.g., the floodplain soils), construction projects, and toxic materials (e.g., oil spills). For the most part, therefore, the streams of the Poplar drainage are used as conveyance systems for the removal of non-point wastes that originated within the basin, and significant volumes of in situ dilution waters should be left in the streams in order to effectively remove these wastes with a minimum degradation of stream quality.

In addition to the non-point problems noted above, the phenomenon of saline seep, which is a natural manifestation of semi-arid areas that can be greatly aggravated by improper crop-fallow practices (8), affords possibly the major land use-water quality problem in the Lower Missouri River Basin (11) and in the Two Rivers Region (45). Agricultural productivity can be greatly curtailed on lands afflicted by these seeps, and this phenomenon can also cause losses to wildlife populations and habitat, livestock, and surface and underground water supplies. The dryland seeps are formed by precipitation and the subsequent infiltration of these waters into salt laden soils; this infiltration solubilizes the salts and carries them into the groundwater solution whereafter the salts can then reappear at the surface below a groundwater discharge point (8, 35). The salts can then be eventually precipitated onto the land following the evaporation and transpiration of these resurfaced groundwaters, creating the white-crusted areas that are diagnostic seeps, or these waters may eventually reach or form saline streams and ponds.

As of 1974, about 18,000 acres of land in Daniels and Roosevelt Counties were affected in this manner (35), and this appears to be a continually growing problem with about 40% more of the acreage in the two county area affected by seeps in 1974 than in 1969 (11). In addition to land effects, surface water qualities can also be greatly affected by the inputs of saline waters from seep areas. The Soil Conservation Service now recommends that the Poplar waters should not be utilized for irrigation during the low flow, late summer months due to their high salinities at this time (54, 62), and this restriction is possibly a reflection to some degree of the recent burgeoning of these saline seep areas. The best quality of water for irrigation from the Poplar River would occur during the high flow months of March, April, and May when runoff waters provide a dilution to these saline effects, and the surface waters are possibly

of a fair quality for irrigation during the moderately high flow months of June and July. In view of the land use and water quality problems that can stem from the development of these seep areas, the State Water Quality Bureau (Montana Department of Health and Environmental Sciences) has suggested that a problem-specific " . . . program should be implemented to control or abate problems created by saline seeps (11)." If such controls are not initiated, this growing seep phenomenon, in conjunction with the possible impacts originating from the Coronach development, is suggested of a definite future threat to irrigated agriculture in the Poplar system, and this is most distinct for the East Poplar River and for the upper segments of the Poplar River mainstem.

SURFACE WATER QUALITY BACKGROUND INFORMATION

DATA AVAILABILITY AND SAMPLING PROGRAMS

Very little water quality information has been collected from the Poplar River drainage prior to 1973. In the early 1970's, the State Water Quality Bureau of the Montana Department of Health and Environmental Sciences (MDHES) collected a few samples from this area as a part of their water quality management planning activities in the region (11), and some early data are available from various Canadian sources, e.g., the Canadian Federal Water Quality Division, for the upper segments of the Poplar Basin. However, with the advent of the Coronach coal-fired, power generation development in about 1973, such water quality sampling efforts became greatly intensified in the Poplar drainage on both sides of the border.

Several sampling programs have been initiated by various Canadian entities; these were started for the purpose of defining the quality of waters in the upper Poplar Basin for developmental reasons and also for the purpose of general monitoring in response to this development. In the first instance, Sheppard T. Powell Consultants and the Saskmont Engineering Company began to sample five stream locations in the East Poplar River drainage for the Saskatchewan Power Corporation. This monitoring program was initiated on March 29 of 1973, and the chemical analyses of samples collected by these firms from this date up to April 9 of 1976 were evaluated as a part of this particular inventory. In the second case, both the Canadian Federal and the Province of Saskatchewan environmental departments have collected water quality samples from several streams in the upper portions of the region. Water quality information obtained by these governmental agencies from October 22, 1974 to March 28, 1977, along with some of the pre-1973 data, was also utilized in this review. Table 5 summarizes the streams and locations and the number of samples that have been collected from each of these sampling sites in the Canadian segment of the Poplar drainage, as these data were available to this inventory.

In the United States portion of the Poplar River drainage, the Montana Water Quality Bureau (WQB) initiated a sporadic stream sampling program in April of 1975, and several samples from each of the major streams in the region were subsequently collected by this agency. However, this program was largely supplanted by a more formal monitoring effort conducted by the United States Geological Survey (USGS). The USGS program was initiated on August 13 of 1975, and monthly samples have been collected from the larger streams of the lower Poplar Basin up to the present time. All of the WQB data and all of the water quality data available from the USGS as of October, 1977 (including collections in August of 1977) were utilized for this inventory. In addition, some water quality data have been collected by the United States Environmental Protection Agency, Region VIII (Technical Investigations Branch, Surveillance and Analysis Division), as a part of their fisheries investigation of the Poplar region (69); these chemical data were also considered in this review. Table 5 summarizes the streams and locations and the number of samples that have been collected by various agencies from the southern portion of the Poplar drainage. Specific parameters that were analyzed through these various water quality monitoring programs will be described in more detail later in this report.

As a result of these Canadian and American sampling efforts, a fair amount of water quality data is now available for this particular drainage system, as

Table 5. Streams sampled, collecting agencies, and numbers of samples collected from streams in the Poplar River Basin (PowSask--Sheppard T. Powell Consultants and the Saskmont Engineering Company; FedCan--Federal Canadian Department of the Environment; ProvSask--Province of Saskatchewan Department of the Environment; USGS--United States Geological Survey; EPA--United States Environmental Protection Agency; WQB--Water Quality Bureau of the Montana Department of Health and Environmental Sciences; p--partial analysis of samples; h--pre-1970 data; IB--international boundary). (The first of two pages.)

Stream	Stream Location	Sampling Agency	Number of Samples
Fife Lake	near Constance, Can.	FedCan	1h
Small unnamed creek feeding the Coronach town reservoir	near Coronach, Can.	PowSask	34
West Branch, East Poplar River (probably the upper reach of Girard Creek)	near Coronach, Can.	ProvSask	6
Girard Creek--outlet from the Coronach town reservoir	near Coronach, Can.	PowSask	37
Girard Creek--inlet to the Coronach town reservoir	near Coronach, Can.	PowSask	24
Calrick Creek	near Coronach, Can.	FedCan	1
East Poplar River	near Coronach, Can.	FedCan 3 FedCan 1h ProvSask 7 PowSask 68	Total-- 79
East Poplar River	at the IB	FedCan 15 ProvSask 6 PowSask 67 USGS 31 EPA 5p WQB 4	Total--128
Cow Creek	near Scobey, Mont.	FedCan	1
East Poplar River	near Scobey, Mont.	USGS 20 WQB 3	Total-- 23

Table 5. Continued.

Stream	Stream Location	Sampling Agency	Number of Samples
East Branch, Middle Fork Poplar River	near Rock Glen, Can.	FedCan	1h
West Branch, Middle Fork Poplar River	near Rock Glen, Can.	FedCan	1h
Middle Fork Poplar River	at the IB	FedCan	1
		FedCan	13h
		USGS	12
		EPA	1p
		WQB	1
		Total--	28
Middle Fork Poplar River	near Scobey, Mont.	USGS	20
		EPA	8p
		WQB	4
		Total--	32
Middle Branch, West Fork Poplar River	near Rock Glen, Can.	FedCan	1
West Fork Poplar River	at the IB	FedCan	9
		FedCan	1h
		USGS	12
		Total--	22
West Fork Poplar River	near Four Buttes-Bredette, Montana	USGS	21
		EPA	8p
		WQB	7
		Total--	36
Poplar River	near Bredette, Mont.	USGS	14
		EPA	5p
		WQB	6
		Total--	25
Overland runoff	north of Poplar, Montana	WQB	1
Poplar River	near Poplar, Mont.	USGS	20
		EPA	9p
		WQB	9
		Total--	38
		Grand Total--	519

suggested by Table 5. Since agencies on both sides of the border have frequently sampled the several international boundary sites in the Poplar drainage, the greatest amount of water quality data, therefore, is available for the streams relative to these specific points. About 63% of the chemical information utilized in this inventory for these border locations was collected by Canadian entities. Data in addition to that summarized in Table 5 have probably been collected from the Poplar region by various agencies but not made available in time for this review.

METHODS OF CHEMICAL ANALYSIS

References describing the methods of chemical analyses utilized by the USGS are cited in this agency's annual Water Resources Data for Montana reports (72). Examples of these citations would include Standard Methods (7), Brown, et al (1970), Barnett and Mallory (1971), Goerlitz and Lamar (1967), Guy (1969), Hem (1970), and so on. Methods utilized by the several Canadian agencies are unknown to this writer at the present time, but it is assumed that these procedures are in accord with those adopted by the various water quality-oriented agencies in the United States. Descriptions of specific methods that were utilized by Canadian laboratories for assessing the various water quality parameters can probably be obtained from the appropriate Canadian entity. Chemical procedures employed by the Environmental Protection Agency in their fisheries survey of the Poplar Basin are summarized in their report (69). Methods adopted by the WQB and the Chemistry Laboratory Bureau of the MDHES are listed in Table 6.

STATISTICAL APPROACH

When relatively small amounts of water quality information are available for a drainage system, tabular presentations of the data can be readily made by simply listing all of the individual values that were obtained for each parameter. However, when large quantities of data have been collected from an area of interest, as is the case for the Poplar Basin at the present time (Table 5), some type of statistical or reference summary has to be applied to the sets of data from each sampling location so that the tabular presentations might take some manageable form. The selection of a few representative analyses from those that are at hand might represent an alternative choice to the statistical summary, but this in turn could lead to an exclusion of critical information. As a result, statistical summaries were chosen as a means for presenting the data that are available to this inventory, and a modification of the statistical methods utilized by STORET (a national data storage and retrieval system) has been applied to this report.

In the STORET summaries, means and maximum-minimum values for each parameter are listed by sampling site along with the number of individual analyses involved in each of the calculations (sample size). Expressions of data distribution, i.e., variance, standard deviation, coefficient of variation, and standard error, are also given for each variable. The advantage of STORET's approach lies in its capacity for summarizing a large amount of variable concentration data in the form of a few numbers. A major disadvantage of the STORET summary, however, resides in its masking of flow-related alterations in parametric concentrations which often leads to markedly high coefficients of variation (e.g., greater than 100%). This difficulty can be circumvented to some extent by first classifying the data on a seasonal basis, in part a flow

Table 6. Methods of water analysis commonly utilized by the State Water Quality and Chemistry Laboratory Bureaus of the Montana Department of Health and Environmental Sciences. (The first of two pages.)

Parameter	Method	Reference*
Total Hardness	EDTA titration	SM
Calcium	EDTA titration	SM
Magnesium	EDTA titration, by difference	SM
Sodium	Atomic absorption	SM
Sodium Adsorption Ratio	Calculated	Hem
Potassium	Atomic absorption	SM
Total Alkalinity	Acid titration	SM
Bicarbonate	Acid titration	SM
Carbonate	Acid titration	SM
Sulfate	Thorin titration, turbidimetric	USGS
Chloride	Mercuric nitrate titration	SM
Fluoride	Alazarin complexone	EPA
Dissolved Solids	Calculated as a sum of the constituents	----
Specific Conductance	Wheatstone bridge	SM
Temperature	Calibrated field thermometer	----
pH	Potentiometric (pH meter)	SM
Dissolved Oxygen	Modified Winkler, azide modification	EPA, SM
Biochemical Oxygen Demand	Five-day sample storage, modified Winkler	SM
Total Organic Carbon	Carbon analyzer (Dohrmann)	SM
Turbidity	Nephelometric, turbidimeter	SM
Suspended Sediment	Fiber glass filtration, gravimetric	SM
Fecal Coliforms	Membrane filter and media incubation	Millipore
Orthophosphate	Single reagent	EPA
Total Phosphate	Persulfate digestion, single reagent	EPA
Ammonia	Colorimetric phenate	EPA
Kjeldahl Nitrogen	Digestion, distillation, phenate	EPA
Nitrite	Diazotization	SM
Nitrate	Hydrazine reduction, diazotization	EPA

Table 6. Continued.

Parameter	Method	Reference*
Aluminum	Atomic absorption	SM
Arsenic	Silver diethyldithiocarbomate	SM
Barium	Atomic absorption	SM
Beryllium	Atomic absorption	SM
Boron	Carmine	SM
Cadmium	Atomic absorption	SM
Chromium	Atomic absorption	SM
Cobalt	Atomic absorption	SM
Copper	Atomic absorption	SM
Iron	Ferron orthophenanthroline	USGS
Lead	Atomic absorption	SM
Lithium	Atomic absorption	SM
Manganese	Atomic absorption	SM
Mercury	Atomic absorption	SM
Molybdenum	Atomic absorption	SM
Nickle	Atomic absorption	SM
Selenium	Atomic absorption	SM
Strontium	Atomic absorption	SM
Vanadium	Atomic absorption	SM
Zinc	Atomic absorption	SM

*SM--APHA, AWWA, and WPCF. 1971. Standard Methods for the Examination of Water and Wastewater. Thirteenth Edition. American Public Health Association.

*Hem, J.D. 1970. Study and Interpretation of the Chemical Characteristics of Natural Water. Second Edition. United States Geological Survey Water-Supply Paper 1473.

*Millipore Corporation. 1972. Biological Analysis of Water and Wastewater. Application Manual AM 302.

*EPA--United States Environmental Protection Agency. 1974. Manual of Methods for Chemical Analysis of Water and Wastes. EPA-625/6-74-003.

*USGS--Brown, E., et al. 1970. Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases. United States Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter A1.

classification, and by then further separating these subsets of data on the basis of flow per se. For this review, such a classification of data was based on the hydrologic pattern of the East Poplar River at the international boundary.

As described previously, the East Poplar, and the Poplar drainage in general, experiences a high flow phase during the months of March, April, and May as a result of snowmelt and spring runoff at this time. Thus, these three months were combined as single season for data classification purposes. Flows during the remaining nine months are much lower on the average than the March-May flows, and they are found to generally decline from June to February in the East Poplar River. This nine month, low flow phase was thereby split into two periods: a warm weather low flow season (June to October) with slightly greater average discharges than the cold weather low flow period extending from November to February. Since low flows can also be obtained during the March-May runoff season, and since relatively high flows can be occasionally obtained during the June-October season because of meteorological events, water quality data collected during each of these two periods were further split on the basis of stream discharge. Where possible, therefore, six groupings of water quality data were obtained for each parameter and sampling site as follows--(1) cold weather low flows, (2) March-May low flows (less than 20 cfs), (3) March-May high flows (20 cfs to 100 cfs), (4) March-May extreme high flows (greater than 100 cfs), (5) warm weather low flows (less than 20 cfs), and (6) warm weather high flows (greater than 19.9 cfs). In the case of the Poplar River near its mouth, the high flow, low flow classification criteria were doubled to account for the greater discharge at this location as a result of its placement below the confluence of the three major forks of the Poplar mainstem.

Following the flow and seasonal separations of water quality data collected from each of the sampling stations, mean, median, maximum, and minimum values were then determined for each parametric data set. With the availability of corresponding flow data, this classification system was found to be applicable to most of the sampling locations in the Poplar Drainage. In several instances, however, some empty sets were obtained due to a lack of water quality data for a particular season and flow range. In some cases, the secondary flow classification could not be applied to the Canadian data due to an absence of discharge information, and the classifications in these instances could be taken only to the seasonal level. Statistical summaries, of course, could not be applied to those stations having only one sample collection, and the results of the various individual analyses were tabulated in these cases. In addition, this classification scheme could not be applied to certain specific parameters having relatively small numbers of analyses; in these instances, mean, median, and maximum-minimum values were determined from all of the data that were available for each of these parameters at each sampling site. Particular parameters having this characteristic will become self-evident in the numerous water quality tables to be presented later in this report.

In contrast to the STORET summaries, variances, standard deviations, coefficients of variance, and standard errors were not computed for the various data sets from the Poplar drainage in favor of establishing a median statistic for each variable. The median expression has an inherent value for statistical summaries in being able to specify a particular point in a data set independent of distributional tendencies; that is, 50% of the values in a distribution are greater than the median whereas 50% are lower than this number. In addition,

comparisons between the mean and the median and between the median and the maximum-minimum values of a data set should afford some insight into the type of data distribution being expressed by any particular variable. In distributions that approach normalcy, the mean and the median values should be closely similar with the median most likely lying central to the maximum and minimum numbers of the data set. In a skewed distribution, however, the median value tends to be non-central and to approach either the high or the low end of the distributional range depending upon the direction of the skew. In addition, as a distribution becomes progressively more skewed, the mean and median values of a distribution tend to become increasingly dissimilar as the distinctly high values or the distinctly low values of a data set begin to weight the mean to either higher or lower numbers. This relates to the fact that this weighting tendency has a much smaller effect on the median statistic than the mean since the median is more dependent upon the number of data bits within a particular concentration range than upon the level of these concentrations per se. As a result, the median is probably more representative of a "typical" parametric value in highly skewed distributions than the mean of this same group of numbers. The fact that entire sets of parametric data from a stream location are often skewed due to the occasional occurrences of runoff events, e.g., the obtainment of relatively low dissolved solids concentrations during these runoff periods, points to the reason for selecting the median value as a means of statistical expression for this particular report.

In addition to the determination of median values, another approach for delimiting the skewness tendency of water quality data is to partition this information on the basis of flow as has been done for this report. As will be demonstrated later, the methods of flow classification utilized in this inventory were apparently quite successful for normalizing the Poplar data since mean and median values are often closely similar through a high proportion of the data sets. Thus, for the purposes of this study, the mean, median, and maximum-minimum statistics would appear to be valid estimators of the central tendencies of the Poplar data sets and adequate descriptors of the distributional features of these flow classified numbers.

PARAMETRIC AND TABULAR CONSIDERATIONS

A wide variety of water quality parameters have been assessed for the Poplar River Basin as a result of the various monitoring projects in the region, but the numbers and types of parameters that were monitored in these programs varied considerably between the sampling agencies and between the many sampling sites. As examples, the Saskmont Engineering Company assessed twenty-five parameters at the East Poplar River-international boundary location whereas the USGS monitored about fifty variables at their Poplar River station near Poplar, Montana; in contrast, the Environmental Protection Agency analyzed only sixteen water quality constituents during their fisheries survey of the drainage. However, certain groups of parameters were consistently monitored by all of the sampling agencies, and these variables form a core of water quality information for the area. Such parameters would include six of the common ions or constituents (calcium, magnesium, sodium, potassium, chloride, and sulfate), a few of the "field" parameters (pH, specific conductance, and turbidity), all of critical nutrients (ammonia, nitrate-nitrite, total phosphorus, and orthophosphate), plus four other variables (total alkalinity, total hardness, dissolved solids, and silica). In addition, thirteen other parameters were less frequently monitored in the region, and although they were analyzed by fewer agencies,

adequate data were still available to allow for a flow classification at most of the sampling sites. These parameters would include temperature, dissolved oxygen (and percent saturation), carbon dioxide-bicarbonate-carbonate, sodium adsorption ratios and percent sodium, three organic nitrogen-related species, fluoride, and boron. On the basis of data abundance, therefore, the thirty variables listed above represent the "major" water quality parameters of this particular inventory.

In addition to these major parameters, numerous other variables were monitored in the Poplar drainage, but the numbers of analyses in these cases were comparatively scarce. For example, phenolphthalein alkalinity, chemical oxygen demand, and color were monitored by only a few agencies; thus, complete sets of data for these variables were available for only three or four of the sampling locations. In turn, suspended sediment, biochemical oxygen demand, total organic carbon, and total and fecal coliforms were assessed so infrequently in the basin that effective flow classifications of these data could be made in only a few rare instances. In addition and as described previously, a number of water quality parameters could not be seasonally classified due to a general lack of information. This would include many of the metals and trace elements (e.g., silver, arsenic, barium, cobalt, chromium, lithium, nickle, strontium, and vanadium) along with chlorophyll, the phenols, and various pesticides. Although abundant data were at hand for a few of the metals at some stations (primarily copper, iron, lead, manganese, mercury, and zinc), except for iron, these constituents were also summarized with the other trace elements, i.e., not seasonally classified, for comparative purposes.

Regardless of the paucity of data for some of the water quality variables, most parameters with available analyses from the Poplar Basin were summarized for this inventory. As a result, between fifty and sixty parameters were typically considered for each Poplar station. All of the data from the various sampling agencies were generally combined by sampling station for the statistical summaries of each parameter. In one case, however, pre-1970 and post-1970 data were treated separately as a result of marked differences in certain parametric concentrations between the two eras. These differences were assumed to be reflective of historic changes in the quality of waters in that particular drainage.

In the tabular presentations of the water quality data, the common chemical symbols of the various constituents were utilized whenever possible. In many cases, the mean, median, and maximum-minimum statistics of the variables are expressed as milligrams per liter (mg/l). Other symbols utilized in the tables and the associated concentrational units plus pertinent footnotes can be listed as follows:

Flow--discharge in cubic feet per second (cfs) where flow in cfs times 0.02832 equals flow as cubic meters per second;
Temp--temperature in degrees centigrade (C);
pH--in standard units;
Clr--color in platinum-cobalt units (standard color units);
Turb--turbidity in Jackson Turbidity Units (JTU);
SC--specific conductance as micromhos per centimeter at 25C;
DS--dissolved solids in mg/l;
DO--dissolved oxygen (O_2) in mg/l;
%Sat--observed concentration of dissolved oxygen relative to that at saturation as a percent;

BOD--five-day biochemical oxygen demand as mg O_2 per liter;
TC--total coliform levels as colony counts (i.e., individuals) per 100 ml of sample;
FC--fecal coliform levels (see TC);
TA--total alkalinity in mg/l as $CaCO_3$;
PA--phenolphthalein alkalinity in mg/l as $CaCO_3$;
TH--total hardness in mg/l as $CaCO_3$;
SAR--sodium adsorption ratio, unitless (see Hem, 1970);
%Na--percentage sodium, " . . . the percentage of total cations made up by sodium (Hem, 1970);"
TN--total nitrogen as mg N per liter;
TKjN--total Kjeldahl nitrogen as mg N per liter;
TON--total organic nitrogen as mg N per liter;
NH_3N--ammonia as mg N per liter;
NO_XN--nitrate (NO_3), or more commonly, nitrate plus nitrite as mg N per liter with nitrite (NO_2) concentrations assumed to be negligible;
TP--total phosphorus as mg P per liter;
OP--orthophosphate (PO_4) as mg P per liter;
COD--chemical oxygen demand as mg O_2 per liter;
TOC--total organic carbon as mg of carbon per liter;
Chl--chlorophyll in micrograms (ug) per liter;
Phenols--a general assessment of the phenolic compounds in mg/l.

In addition, the following statistical symbols were used in the tables:

N.--the number of analyses available for a particular flow and seasonal subset of a parameter for each sampling station;
Min--the minimum value of a data subset;
Max--an alternate name for a Botz, or the maximum value of a data subset;
Mean--the average value of a data subset;
Med--the median, "middle", or fifty percentile value of a data subset.

An "E" in the various water quality tables points to an estimated value. This symbol was most commonly utilized to designate an estimated rather than a measured flow, although a few of the DS and SC values in the tables were also estimated through the use of the following equation: DS = 0.69 SC. The "D" and "T" expressions in the tables denote the dissolved and the total recoverable (acid extractable) forms of the trace elements respectively. Trace element data from the WQB and several other agencies were most generally analyzed as total recoverable metals, for example, with the laboratory analyses performed on unfiltered, acid- fixed samples. However, the USGS and a few Canadian agencies have also assessed the dissolved form of most of these trace elements. This analysis involves a filtration step immediately following sample collection with the acid fixation and the laboratory work then performed subsequent to this filtration procedure. Data for the dissolved and total recoverable forms of the trace elements were kept separate for the statistical tabulations.

With respect to the pesticides, data for the various species of this parameter group were combined by station prior to the statistical analyses due to the general scarcity of this type of information. Individual pesticides that were analyzed by various agencies for samples from the Poplar drainage and the corresponding concentrational ranges for the basin can be listed as follows: 2,4,5-T (<.002 ug/l with N.=6), 2,4-DB (<.009 ug/l with N.=2), 2,4-D (<.004 ug/l to 0.08 ug/l with N.=6), 2,4-DP (<.004 ug/l with N.=1), MCPA (<.2 ug/l with N.=1),

and Lindane (<.001 ug/l to 0.001 ug/l with N.=4).

MONTANA WATER USE STREAM CLASSIFICATIONS AND WATER QUALITY STANDARDS

Surface waters in the Poplar River Basin have been classified as $B\text{-}D_2$ streams by the State of Montana (44). The State's "Water Quality Standards" define a $B\text{-}D_2$ stream as one in which the "quality is to be maintained suitable for drinking, culinary, and food processing purposes after adequate treatment equal to coagulation, sedimentation, filtration, disinfection and any additional treatment necessary to remove naturally present impurities; bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply (44)." This definition is almost identical to that of the $B\text{-}D_1$ and $B\text{-}D_3$ classifications except that a $B\text{-}D_1$ designation requires the "growth and (non-marginal) propagation of salmonid fishes" (a cold water fishery) while a $B\text{-}D_3$ designation requires the "growth and propagation of non-salmonid fishes" (a warm water fishery)(44). The B-D stream classifications, in turn, stand in contrast to the various A and C designations: an A-type of water has a higher quality than the B-D stream in requiring a less sophisticated level of treatment prior to human use; a C stream has a lower quality of water that is generally unsuitable for drinking, culinary, and food processing purposes while being adequate for recreation, aquatic life, and agricultural-industrial supply (44). Streams possessing an E-F designation have a relatively poor quality of water that is of value primarily for agricultural and industrial uses (44). According to the State's stream classification system therefore, waters in the Poplar drainage can be described as being adequate for a borderline cold water fishery (and associated aquatic life) with a fairly good quality of water that can be applied to most beneficial uses after appropriate treatment.

Coliform and dissolved oxygen criteria that have been established by the State of Montana for $B\text{-}D_2$ streams can be stated as follows (44):

> The average number of organisms in the fecal coliform group is not to exceed 200 per 100 milliliters nor are 10 percent of the total samples during any 30-day period to exceed 400 fecal coliforms per 100 milliliters. The average number of organisms in the coliform group is not to exceed 1,000 per 100 milliliters nor are 20 percent of the samples to exceed 1,000 coliforms per 100 milliliters during any 30-day period.
>
> Dissolved oxygen concentration is not to be reduced below 7.0 milligrams per liter from October 1 through June 1 nor below 6.0 milligrams per liter from June 2 through September 30.

State criteria for pH, turbidity, sediment, and color in $B\text{-}D_2$ streams such as the Poplar River are summarized below (44):

> Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 9.0 is to be less than 0.5 pH unit. Natural pH outside this range is to be maintained without change. Natural pH above 7.0 is to be maintained above 7.0.
>
> The maximum allowable increase above naturally occurring turbidity is 10 Jackson Candle Units . . . .

> No increases above naturally occurring concentrations of sediment, settleable solids or residues, which adversely affect the use(s) indicated, are allowed.
>
> True color is not to be increased more than five units above naturally occurring color.

In the case of toxic and other deletrious substances the State of Montana makes the following recommendation for B-D_2 streams (44):

> Concentrations of toxic or other deleterious substances, pesticides and organic and inorganic materials including heavy metals, after treatment for domestic use, are not to exceed the recommended limits contained in the 1962 U. S. Public Health Service Drinking Water Standards or subsequent editions, and no increase of more than 10 percent of the concentration present in the receiving water is permitted . . . .

As an example of a Public Health Service (PHS) quality standard, this agency recommends that concentrations of phenolic compounds should not exceed 0.001 mg/l if the water is to be utilized for human consumption (73). Other standards for a variety of water quality parameters have been similarly developed by the PHS, and these various criteria will be considered in greater detail elsewhere in this report.

Temperature standards adopted by the State of Montana for B-D_2 streams (44) allow for a " . . . 1°F (fahrenheit)(0.56C) maximum increase above naturally occurring water temperature . . . within the range of 32°F to 66°F (from 0.0C to 18.89C); within the naturally occurring range of 66°F to 66.5°F (from 18.89C to 19.17C), no discharge is allowed which will cause the water temperature to exceed 67°F (19.44C); and where the naturally occurring water temperature is 66.5°F or greater, the maximum allowable increase in water temperature is 0.5°F (0.28C). A 2°F (1.11C) per hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55°F (12.78C), and a 2°F maximum decrease below naturally occurring water temperature is allowed within the range of 55°F to 32°F (from 12.78C to 0.0C).

WATER QUALITY REFERENCE CRITERIA

Rationale and General Criteria

The concept of a "quality" of water is rather ambiguous at best since any particular "quality" is dependent to a large degree upon the specific uses of a water and upon the precepts of the people that are describing the water. Thus, discussions of water quality often prove to be quite tedious without some definite point of reference. Due to this ambiguousness, a great deal of attention has been devoted in recent years to a quantification of the quality concept, and this has ultimately led to the development of a water quality index (WQI) wherein the qualities of various waters are expressed by single numerical values. In the WQI developed by Brown et al (1970) and applied to the Kansas River Basin (40), index values range from zero to 100 with the better quality of waters demonstrating the higher numbers. Although such numerical expressions have their application in a general descriptive sense, nevertheless, the level of quality exhibited by a certain water is still largely dependent upon the particular water uses of its drainage basin. That is, the quality needed

for stock water is different from that required for man's consumption and domestic use, and the quality considerations of a stream could vary considerably between that of a stockman and that of a water treatment plant operator. As a result, some basis of discussion other than the WQI is necessary in most instances.

Numerous water quality criteria have been developed through the years that describe the critical concentrational levels of those variables that are important to the successful conclusion of a specific water use. These criteria, thereby, should also specify the requirements for a good quality of water relative to any particular application. As a result, these criteria and standards can serve as a reference point for evaluating a body of water and the levels of its biological, physical, and chemical constituents, and such criteria can also provide a discussional base for the assessment of surface waters in any given study region such as the Poplar Basin. To this end, literature sources were reviewed for those criteria and standards that will delineate the critical concentrations of important parameters in reference to the water uses of the Poplar region. These specific reference criteria will be considered in more detail later in this report.

In addition to the specific criteria noted above, various general reference criteria are also available for certain water quality parameters. Although these criteria are descriptive in nature and not delineative of critical water use concentrations, they are of value for describing particular water quality attributes of a study region. The WQI described previously would serve as an example of a general reference criteria; however, WQI values have not yet been calculated for samples from the Poplar Basin. Added examples would include the two classification systems that have been developed to define various levels of hardness (10, 19) and salinity (58):

Hardness Range (mg/l of $CaCO_3$)	Description
0 to 60	Soft
61 to 120	Moderately hard
<80	"Ideal"
121 to 180	Hard
>180	Very hard

Salinity Range (mg/l)	Description
<50	Non-saline (rain and snow)
<1000	Non-saline (most freshwater)
1,000 to 3,000	Slightly saline (some freshwater)
3,000 to 10,000	Moderately saline (estuaries)
10,000 to 35,000	Very saline (oceans and estuaties)
>35,000	Briny (miscellaneous aquatic systems)

Certain of the water quality standards established by the State of Montana (44) can also serve as general reference criteria. For some parameters, the standard specifies an allowable, maximum change in stream concentration rather than a specific upper limit, e.g., turbidity, and this type of standard is not amenable to its use as a reference value. However, definite limits or ranges of limits have been established for other parameters by the State, and such recommended levels for these parameters can be utilized for this purpose. Ap-

plicable water quality standards in this regard for B-D_2 streams are summarized in Table 7.

Agricultural Criteria--Stock Water

Stock animals are generally more tolerant to saline waters than most types of crop species, i.e., more tolerant to high dissolved solids (DS) concentrations. In turn, it appears that domesticated animals can tolerate much higher salinities than man, although greater productivities are generally obtained from these animals if waters suitable to man are also made available to stock (41). In general, waters containing less than 5,000 mg/l can be used continuously by all livestock (41), although much lower concentrations of particular ions could have detrimental effects.

The California State Water Quality Control Board (16) lists the threshold concentration of DS for stock at 2,500 mg/l and the limiting concentration at 5,000 mg/l. A limiting concentration implies a marked impairment to the animals after extended consumption whereas a threshold concentration denotes that level where relatively mild physiological effects are first observed to occur. However, limiting tolerances to salinity can vary considerably between groups of animals with sheep, for example, much more tolerant than cattle and cattle more tolerant than pigs. Dairy cows are more sensitive than beef cattle, and milk production in the dairy animals is curtailed by waters having more than 1750 mg/l of TDS (41). The Department of Agriculture of Australia has done extensive work on the effects of saline waters on a variety of stock animals due to the highly mineralized nature of the water that has to be utilized for this purpose in the western portions of this country (3, 4). From this work, some conclusions have been drawn concerning the threshold concentrations of DS that can be tolerated by various types of livestock; safe upper limits for these different animals as reported by this agency and summarized by McKee and Wolf (1963) are listed in Table 8. Salinity classification schemes developed by the States of Montana (61) and South Dakota (5) and by the United States Environmental Protection Agency (24) are also summarized in this table.

The physiological effects of dissolved solids on livestock, however, can also vary within the different groups of animals listed in Table 8. These variations are dependent upon feed, life stage and age, physiological condition, season, period of consumption, and preconditioning (41). As a result, the several salinity criteria presented in this table are intended to be used only as general guidelines. Additional affecting factors are the quality and quantity of salts in an animal's diet and the proportions and types of salts in an animal's water supply. Stock water criteria for the common ionic constituents and for several of the metals are available from the California State Water Quality Control Board (16) and from the Environmental Protection Agency (24), and the critical concentrational levels of these parameters are included in Table 8.

Agricultural Criteria--Irrigation Water

Salinity and the common ions.

In contrast to the relatively specific reference criteria that are available for animals (including man), criteria for irrigation water are, of necessity, much more arbitrary and flexible because of the many variables that are involved--soil solution-surface water differences in quality and quantity, tol-

Table 7. Water quality reference criteria selected from Montana's Water Quality Standards--MAC 16-2.14 (10)-S14480.

Field Parameters

Fecal Coliforms (number per 100 ml) Average Number	10% (a) Maximum	Minimum Dissolved Oxygen (mg/l) (b)	pH (c) Range	Maximum Temperature (d)
200	400	cold weather--7.0 warm weather--6.0	6.5 to 9.0	cold water fishery--19.4C warm water fishery--26.7C

Metals (e) (mg/l)

Parameter	Average Daily Concentration	Maximum Instantaneous Concentration
Total Arsenic	0.010	0.010
Total Cadmium	0.010	0.010
Total Copper	0.050	0.090
Dissolved Copper	0.030	0.030
Total Iron	0.300	1.300
Dissolved Iron	0.150	0.150
Total Lead	0.050	0.050
Dissolved Lead	0.050	0.050
Total Mercury	0.001	0.001
Total Zinc	0.100	0.200
Dissolved Zinc	0.070	0.080

(a) Ten percent of the total number of samples obtained in a thirty-day period are not to exceed this value.

(b) Dissolved oxygen concentrations are not to be reduced below these values.

(c) No changes of pH are allowed outside of these values.

(d) No increases of temperature are allowed above these limits when the water's naturally occurring temperature is about 0.3C below these values.

(e) Standards adopted for the lower Clark Fork River drainage in northwestern Montana.

Table 8. Various water quality reference criteria for stock in mg/l as modified from five sources: California State Water Quality Control Board (1963), "Water Quality for Livestock"; Environmental Protection Agency (EPA) (1973), "Water for Livestock Enterprises" in Water Quality Criteria, 1972; McKee and Wolf (1963), "Stock and Wildlife Watering" in Water Quality Criteria; Seghetti (1951), Montana salinity classification; and South Dakota State College Agricultural Experiment Station (1959), "Salinity and Livestock Water Quality."

California State Water Quality Control Board

	pH	Dissolved Solids (DS)	HCO_3	Ca	Cl	F	Mg	Na	SO_4	As
Threshold Level	6.0 and 8.5	2500	500	500	1500	1.0	250	1000	500	
Limiting Level	5.6 and 9.0	5000	500	1000	3000	6.0	500	2000	1000	1.0

Environmental Protection Agency

	Al	As	B	Cd	Cr	Co	Cu	F	Pb	Hg	NO_2+NO_3-N	NO_2-N	Se	V
Recommendation	5	0.2	5.0	0.05	1.0	1.0	0.5	2.0	0.1	0.01	100	10	0.05	0.1

Threshold salinity (DS) levels for various animals (McKee and Wolf)

Animal	Salinity Level
Poultry	2860
Pigs	4290
Horses	6435
Cattle, Dairy	7150
Cattle, Beef	10,000
Adult Dry Sheep	12,900

Use and effect of saline waters on livestock and poultry (EPA)

<1000: excellent for all stock

1000-3000: very satisfactory for livestock and poultry, temporary effects, if any

3000-5000: satisfactory for livestock, poor for poultry

5000-7000: permissible for livestock, unacceptable for poultry and lactating animals

7000-10,000: somewhat risky with older livestock and poor for swine, unacceptable for young and lactating animals and for poultry

>10,000: generally unsuitable for most animals

Montana (MT) and South Dakota (SD) salinity classifications

Water Class	Salinity Range
Excellent	<1000 (SD)
Good	<2500 (MT)
Good	1000-4000 (SD)
Fair	2500-3500 (MT)
Satisfactory	4000-7000 (SD)
Poor	3500-4500 (MT)
Unfit	>4500 (MT)
Unsatisfactory	>7000 (SD)

erance differences between species of plants, differences in soil-type and climate, synergistic and antagonistic relationships between ions, different management practices, and so on. As a result, specific assessments of particular irrigation systems can become exceedingly complex, and general limits for salinity, therefore, cannot be made too fixed or rigid (41). Considerations of irrigation in the Poplar drainage will be largely water-oriented rather than soil-, plant-, or climate-oriented since the qualities of water in this region form the central theme of this study. Attention will be directed primarily towards the total salts or dissolved solids which have osmotic effects and towards certain of the cations-anions; however, the plant and soil factors in irrigation assessments will also be given some consideration in this inventory as will the trace substances which can be either limiting as essential nutrients or toxic to plant growth in extremely low or high concentrations respectively.

Waters for irrigation are typically divided into broad categories such as "excellent", "good", "injurious", "unsatisfactory", and so forth with a set of applicable chemical ranges associated with each water class. Crop species are then associated with one of these water classes in terms of their abilities to tolerate its chemical characteristics, and the plants are, in turn, classified on this basis as "tolerant", "semi- or moderately tolerant", or "sensitive". McKee and Wolf (1963) conducted an extensive survey of the literature and developed the classification scheme for irrigation waters presented in Table 9. The chemical criteria in this table can be used to judge the quality of waters in the Poplar River Basin relative to their use in the watering of various plant species. In addition, adequate research has been completed to allow for the salinity classification of various cultivated plants and forage species; the listing in Table 10 includes those crops that might conceivably be grown in the Poplar drainage on a commercial or private-garden basis (57). All of the forage species listed by Allison (1964) are included in this table.

The United States Department of Agriculture (USDA) lists four broad levels of salinity (57) (expressed as the specific conductance of a water) which can be utilized to classify the waters of the Poplar drainage--a low salinity hazard with specific conductances (SC) less than 250 micromhos (umhos), a medium salinity hazard with SC's between 250 and 750 umhos, a high salinity hazard with SC's between 750 and 2250 umhos, and a very high salinity hazard with SC's greater than 2250 umhos. The USDA suggests a restriction of irrigation waters at 750 umhos when applied to only moderately salt tolerant crops. They further suggest that waters with conductivities over 2250 umhos are unsuitable for continuous use while waters ranging between 750 and 2250 umhos can be used for crops with a good salt tolerance on well-drained soils. Thorne and Peterson (1954) are in general agreement with the USDA and with the classification system of McKee and Wolf (1963) in allowing the use of waters with SC's up to 2250 umhos for the irrigation of crops with moderate to good salt tolerances on soils with moderate to good permeabilities. However, the National Technical Advisory Committee (1968) is somewhat more restrictive than the USDA in recommending a maximum limit of 1500 umhos for irrigation since waters with conductivities above this value " . . . may have adverse effects on many crops (48)."

Apart from salinity per se, certain of the ionic constituents of a irrigation water may also have adverse effects upon cultivated plants when present in high concentrations, as indicated in Table 9. Another system of water classification for irrigation relates to the concept of "potential salinity" involving chloride and sulfate concentrations in milliequivalents per liter (me/l)

Table 9. Summary classification of irrigation waters and recommended maximum concentrations of trace elements for all plants in continuously used irrigation waters; modified from McKee and Wolf (1963), "Agricultural Water Supply (Irrigation)" in Water Quality Criteria, and from the Environmental Protection Agency (1973), "Water for Irrigation" in Water Quality Criteria, 1972.

Water Class	Na%	SAR	Cl(me/l)	SO_4(me/l)	Specific** Conductance	TDS (mg/l)	Salinity Hazard
I	<30-60%*	<1.0-4.2*	<2-5.5	<4-10	<500-1000*	<700	low-medium
II	30-75%	1.0-11.6	2-16	4-20	500-3000	350-2100	medium-very high
III	>70-75%	>9.0-11.6	>6-16	>12-20	>2500-3000	>2500-3000	very high

*Recent work favors the upper limit. **In micromhos per cm at 25C.

I - Excellent to good, suitable under most conditions.
II - Good to injurious, harmful under certain conditions of soil, climate, and management practices.
III - Injurious to unsatisfactory, unsuitable under most conditions.

I - Suitable for irrigation of all or most plants, including the salinity sensitive species.
II - Not suitable for most salinity sensitive plants; suitable for all tolerant and for many semi-tolerant species.
III - Unsatisfactory for most plants except those that have a high tolerance to saline conditions.

(mg/l)	Al	Be	Cd	Cr	Co	Cu	F	Fe	Pb	Li	Mn	Mo	Ni	Se	V	Zn
Recommendation	5.0	0.1	0.01	0.1	0.05	0.2	1.0	5.0	5.0	2.5	0.2	0.01	0.2	0.02	0.1	2.0

Table 10. Relative tolerances of various crops and forage species to salinity arranged according to decreasing tolerances within groups; modified from Allison (1964) and from Hem (1970).

Tolerant--------- to ----------Semi-Tolerant and Moderately Tolerant---------- to ------Sensitive

Field, Truck, and Fruit Crops

Barley	Garden Beets	Tomato	Bell Pepper	Field Beans
Sugar Beet	Kale	Broccoli	Carrot	Radish
Rape	Asparagus	Cabbage	Onion	Green Beans
	Spinach	Cauliflower	Peas	Apple
	Rye	Lettuce	Squash	Boysenberries
	Wheat	Sweet Corn	Cucumber	Blackberries
	Oats	Potato		Raspberries
	Corn			Strawberries
	Flax			
	Sunflower			

Forage Species

Saltgrass	Sweetclover	Oats (hay)	White dutch clover
Bermudagrass	Perennial ryegrass	Orchardgrass	Meadow foxtail
Tall wheatgrass	Mountain brome	Blue grama	Alsike clover
Rhodesgrass	Harding grass	Meadow fescue	Red clover
Canada wildrye	Beardless wildrye	Reed canary	Ladino clover
Western wheatgrass	Strawberry clover	Big trefoil	Burnet
Tall fescue	Dallisgrass	Smooth brome	
Barley (hay)	Sudangrass	Tall meadow oatgrass	
Birdsfoot trefoil	Hubam clover	Milkvetch	
	Alfalfa	Sourclover	
	Rye (hay)		
	Wheat (hay)		

(17, 18). Limiting salinities in this system are "graded" on the basis of a broad, soil-leaching factor that is described by a soil's percolation rate (Table 11). In addition to chloride and sulfate, Eaton (1950) also stresses the importance of bicarbonate ions in quality assessments. As the soil solution tends to become concentrated, high bicarbonate levels could result in the precipitation of calcium and magnesium if pH values happened to increase. The relative proportion of sodium would thereby increase producing an increase in the sodium hazard of the soil solution (41). This bicarbonate factor is termed "residual sodium carbonate" (RSC) and is defined as the difference between bicarbonate plus carbonate and calcium plus magnesium in me/l (Table 11). The "residual" carbonate of the irrigation water would precipitate calcium and magnesium ions since the carbonate salts of these cations are relatively insoluble. This is unfavorable since calcium and magnesium maintain the soil in a good condition when in proper proportions whereas sodium tends to destroy a soil's structure and tilth when it predominates (41). As a result, relative sodium concentrations, expressed as percent sodium or as SAR (sodium adsorption ratio) are also important features to consider in the quality assessments of irrigation waters (Table 9).

Similar to the case of salinity, the USDA has also classified the sodium aspect of irrigation waters into four broad categories based on SAR values (57)--a low sodium hazard with relatively low SAR's (less than 10), medium and high salinity hazards with intermediate SAR levels between 2.5 and 18 and between 7.0 and 26 respectively, and an extremely high sodium hazard with SAR values greater than 11.5. Unlike the categories for salinity, however, the ranges of the different sodium classes are quite variable, overlapping to a considerable degree due to the dependence of this classification system on the SC of a particular water. That is, a particular SAR may represent a low sodium hazard under relatively low SC levels, but it may also denote a medium or even high sodium hazard with the increasing salinity of a sample. Thus, the USDA system for sodium is not as straightforward as that for salinity, but if SAR and SC values are available, it can be utilized to qualitatively describe the value of a water relative to its potential sodium impact on an irrigated area.

Boron and other constituents.

Along with salinity and certain of the common ions, high boron concentrations can also degrade the quality of a water for irrigational applications. This type of problem is most common in the southwestern United States where many of the studies on boron toxicities have been conducted (36). Water quality degradations due to boron do not appear to be of major import to the State of Montana as a whole since the average boron concentration of major surface waters in this State approaches only 0.1 mg/l (12), which is near the detection limits of the constituent. However, the Poplar Basin appears to represent a unique case for Montana since preliminary surveys conducted by the WQB have indicated that this constituent may pose a major threat to the use of irrigation water from this particular drainage system. Thus, boron will receive a great deal of attention in this regard in the later chapters of this review.

Adequate research has been conducted in the boron toxicity problem to afford the establishment of various reference criteria for this constituent (2, 32, 57). Like the case for salinity, these criteria have to be plant-dependent to a large degree since the tolerances of cultivated plants to high boron levels are quite variable between species. Thus crop plants are general-

Table 11. Critical potential salinity and residual sodium bicarbonate (RSC) values in waters used for irrigation. Modified from Doneen (undated) and Eaton (1950).

	Limiting Potential Salinity*		
Water Class:	Class I	Class II	Class III
Soil Condition			
A (poor)	3	3-5	5
B	5	5-10	10
C (good)	7	7-15	15
RSC**	<1.25(a)	1.25-2.50(b)	>2.50(c)

* Potential salinity = $Cl + 0.5\ SO_4$ in milliequivalents per liter.
** RSC = $(CO_3 + HCO_3) - (Ca + Mg)$ in milliequivalents per liter.

(a) Safe waters.
(b) Marginal waters, used successfully with good management practices.
(c) Unsuitable water for irrigation.

Class I--Excellent to good, suitable for most plants under most conditions.
Class II--Good to injurious, harmful to some under certain conditions of soil, climate, and practices.
Class III--Injurious to unsatisfactory, unsuitable under most conditions.

Soil A--Little leaching owing to low percolation rates.
Soil B--Some restricted leaching, slow drainage.
Soil C--Open soils with easily accomplished, deep percolation and leaching.

ly graded as being "tolerant", "semi-tolerant", or "sensitive" to this water quality variable. A particular water, in turn, is rated as "excellent", "good", "permissible", and so on, for irrigation on the basis of its boron concentrations and in relation to the relative tolerances of the crops being grown and irrigated in the region of interest. This information is summarized in Table 12 with respect to the types of commercial plants that might be conceivably grown in the Poplar drainage. The stock water reference criterion for boron is presented in Table 8.

In addition to its toxicity at high levels, boron also acts as an essential nutrient, and plant growth and agricultural productivity can be severely retarded when this constituent is below a certain critical level in the soil. Similar to boron, this high level-low level dichotomy in plant effects is also evident in several of the other trace elements, such as iron, zinc, copper, and manganese, although most of the trace elements are not required by plants as nutrients and have only toxic effects, e.g., lead, mercury, cadmium, and chromium. No reports have been made for the Poplar drainage concerning the action of any of these trace elements in retarding agricultural productivity as limiting nutrients, at least to the writer's knowledge. The most commonly deficient elements in an agricultural sense are certain of the macronutrients, including nitrogen, phosphorus, and potassium, which are commonly applied to the land as fertilizers. But a discussion of such deficiencies in the Poplar Basin and the associated water quality implications is far beyond the scope of this review, except for the standpoint of non-point agricultural pollution reaching the basin's streams. As a result, only the toxic rather than the nutritive aspects of the trace elements will be considered in this inventory. Reference criteria for those trace elements having toxic effects on cultivated plants have been recently summarized by the Environmental Protection Agency (24), and these reference values are listed in Table 9.

Plant and soil relationships.

As indicated previously, the soil characteristics of a particular region can play a major role in determining the value of an irrigation water. A similar arguement can be made for the types of plants to be grown in an area, and as a result, some consideration should be given to these factors in light of the reference criteria for irrigation. As an example, alfalfa is probably the most commonly irrigated crop in the Poplar drainage, although some irrigated acres might also be devoted to western wheatgrass, barley, and wheat (36). Therefore, since alfalfa is economically important to the basin in terms of acreage and yield, and since this crop is generally less tolerant to salinity than the other three species (Table 10), considerations of water quality in the study area in relation to irrigation should revolve primarily around this particular plant.

With respect to the soil factor, a certain amount of leaching is necessary in order to prevent salt buildup in a soil, and each soil has a leaching requirement (LR) that is ideal for its particular characteristics. Features of the four major types of soils in the Poplar River Basin are summarized in Table 1. If a salt balance is to be maintained in these soils, i.e., if the salt carried away by the drainage is to equal that added via the irrigation water, then the LR factor can be described by the following equation: $LR = SC_I/SC_D\ (100)$. In this equation, SC_I is the electrical conductance of the irrigation water, and SC_D is the conductance of the drainage waters. Klages (1976) suggests that a LR value between 20% and 25% might be reasonable for the Poplar area soils which are characterized as having slow to moderate permeabilities (probably the A and

Table 12. Water-related and plant-related reference criteria for boron. Data in set I was taken from the United States Salinity Laboratory Agricultural Handbook No. 60 (Richards, 1954), and information in set II was modified from Allison (1964) and Hem (1970).

I. Rating system for boron in irrigation waters as milligrams per liter.

	Crop Tolerances		
Water Class	Sensitive	Semi-Tolerant	Tolerant
Excellent	<.33	<.67	<1.0
Good	0.33 to 0.67	0.67 to 1.33	1.00 to 2.00
Permissible	0.67 to 1.00	1.33 to 2.00	2.00 to 3.00
Doubtful	1.00 to 1.25	2.00 to 2.50	3.00 to 3.75
Unsuitable	>1.25	>2.50	>3.75

II. Relative tolerances of crop plants to boron arranged according to decreasing tolerances within each group.

Sensitive (0.3-1.0 mg B/l)	Semi-Tolerant (1.0-2.0 mg B/l)	Tolerant (2.0-4.0 mg B/l)
American Elm	Sunflower	Asparagus
Apple	Potato	Sugar Beet
Blackberries	Tomato	Garden Beet
	Sweet Peas	Alfalfa
	Radish	Gladiolus
	Field Peas	Broadbean
	Barley	Onion
	Wheat	Turnip
	Corn	Cabbage
	Oats	Lettuce
	Bell Pepper	Carrot
	Zinnia	Western Wheatgrass

B type of soils in Table 11).

Using a LR value of 22% as representative of the Poplar drainage, an application water with a SC of about 1800 umhos will afford a SC in the soil saturation extract and drainage waters of about 8000 umhos, assuming that adequate volumes of irrigation water are added to leach the soil; in this case, about 1.25 inches of water would have to be added per each inch of water utilized by the plants. For alfalfa, a value of 8000 umhos in the saturation extract will result in a 50% reduction in yield (36). If this reduction in yield can be tolerated, according to the LR equation, an irrigation water with a SC of about 1800 umhos can be applied to the soil. However, a lower SC water would have to be added to those plants having a lower sensitivity to salinity than alfalfa in order to obtain a similar decline in yield, and the opposite case would apply for those plants having greater tolerances such as barley and western wheatgrass. In turn, if irrigation waters with a higher SC than 1800 umhos are added to an alfalfa crop, then further reductions in yields might be expected to accompany the greater SC levels in the saturation extract; if smaller yield reductions than 50% are wanted, then waters with lower SC values would have to be applied to the soils. Thus, the water quality requirements of a particular irrigation system also depend to some degree upon the requirements and preceptions of the area's farmers.

Klages (1976), after reviewing the reference criteria and the available water quality, plant, and soil data for the Poplar Basin, points out that since " . . . the crop (alfalfa) is only moderately tolerant (to salinity) and the two most important soils are moderate and slow to moderate in permeability, it seems that this would restrict the allowable conductivity to . . . less than 1.5 mmhos/cm." This value for salinity then, 1500 umhos, might be viewed as an irrigation reference criterion that is specific for the Poplar drainage. In the case of the region's major irrigated crops, this value will provide a yield reduction that is less than 50% and a soil saturation extract having a SC of about 6800 umhos.

In addition to salinity, the sodium factor in irrigation waters represents another quality feature that is dependent upon the soil characteristics of a region. The critical level of sodium in a soil is usually taken as 15% of the cation exchange capacity (CEC), although the actual allowable amount depends upon the quantities and kinds of clay that are present (36). In general, fine-textured soils and soils with swelling clays are affected at less than 15% CEC (57), and Montana soils often fall into this category. For example, research with Valley County soils, located directly to the west of the Poplar Basin, has demonstrated that an 8% CEC is adequate to significantly reduce soil aggregation and percolation rates (36). Unfortunately, no CEC data of this kind are available for the Poplar drainage at the time of this writing. However, some soils work is now being done in the region, and such CEC data, when made available, will afford the opportunity to develop specific sodium criteria for the Poplar waters. For the time being, some relatively crude estimates can be made of critical SAR values in the drainage.

In a review recently completed by Klages (1976) dealing with the sodium factor, he indicates that at a SC of 1500 umhos, which is assumed to be tolerable for the Poplar soils and for alfalfa, almost . . .

> all soils could tolerate an SAR of 5 in irrigation waters and all but fine textured soils could tolerate an SAR of 10 (57). The Lohler soil

has been classed as fine textured with montomorillonitic clay (Table 1) and thus should not have water with SAR over 5. The equilibrium ESP (exchangeable sodium) values associated with these SAR values are 6 and 12 respectively. Thus, Montana research indicates that SAR 10 is probably too high even for the Havrelon soil. The high content of carbonate and bicarbonate gives another reason for caution about high SAR. Bower and Wilcox derived an equation for the amount of calcium and magnesium in irrigation water precipitated by carbonate and bicarbonate (13). Calculations with waters having the analyses (typical for the Poplar drainage) . . . show that the SAR would likely be raised about 0.5 as a result of calcium and magnesium carbonate precipitation.

Klages (1976) concludes that " . . . average SAR values should not be above 7.5 to 8.0 (in irrigation waters from the Poplar drainage), and even this may cause problems on fine textured soils." Thus, these values for SAR can be utilized as preliminary reference criteria for sodium that are specific for the Poplar area.

Drinking Water and Surface-Public Supply Criteria

As noted previously, many of the waters utilized for domestic and municipal supplies in the Poplar Basin are obtained from shallow alluvial wells. One authority indicates that these shallow groundwater systems are probably recharged to a large extent by the Poplar River (54). This is illustrated in Table 13 by the close similarity of Scobey, Montana, well water samples to those obtained from the East Poplar River and the Middle Fork Poplar River during similar seasons; and these data stand in contrast to the qualities that were obtained from unrelated groundwater collections. This groundwater-surface water interrelationship suggests that groundwater supplies could be ultimately affected by the Coronach development through the inputs of impacted surface waters into groundwater systems. As a result, some attention should be directed to those reference criteria that have been established for the human use of water. The United States Public Health Service (1962) recommendations for maximum concentrations of various water quality parameters in drinking water, as referenced by the State of Montana's "Water Quality Standards (44)," are summarized in Table 14. These criteria are based on waters that have been treated prior to dispersal into public supply systems, as noted in the table. Criteria for untreated, surface-public supply waters are also listed in the table as obtained from other references (24, 48).

Man is typically more sensitive to salinity and high concentrations of common ions than the other animals, and as a result, the acceptable levels of these constituents for human consumption are generally more stringent than those established for livestock. Thus, a water that may be adequate for stock may not be suitable for domestic use and municipal supply. The PHS recommends that waters containing dissolved solids in excess of 500 mg/1 should not be used for drinking water if other more potable and less mineralized sources are or can be made available (73). The National Technical Advisory Council accepts 250 mg/1 of DS as a "desirable" level with 500 mg/1 of DS deemed "permissible" in surface waters that are utilized for public supply (48). However, these reference levels are primarily based on aesthetic features such as taste, and the acceptance of a high DS water and its associated taste problems, therefore, is contingent upon local reactions and upon the availability of alternative supplies. For example, 100 public supplies in the United States had waters with DS levels in

Table 13. Comparison of chemistries in Scobey, Montana, well samples obtained from alluvial groundwater sources to samples collected from the East and Middle Fork Poplar River and from other groundwater systems. Analyses are presented as milligrams per liter.

Parameter	Middle Poplar* (11/76)	East Poplar* (11/76)	Surface Water Average	Scobey Well** (11/66)	Scobey Well** (10/76)	Simms Spring** (3/76)	Hydumas Well** (4/76)	Pittengens Well** (4/76)	Unnamed Well* (9/75)
DS	1030	927	979	850	1235	456	3370	869	1340
TH	240	380	310	220	265	185	1420	158	13
Ca	34	73	54	40	33	45	288	28	2.9
Mg	37	49	43	29	44	18	170	21	1.0
Na+ K	298	208	253	276	258	17	475	185	432
HCO_3	663	645	654	600	600	223	622	494	612
SO_4	300	260	280	276	288	20	1760	135	7.4
Cl	12	4.9	8.5	18	11	6.3	59	5.6	160
NO_3-N	0.01	0.21	0.11	0.41	0.05	0.77	--	--	0.03
F	0.6	0.3	0.45	0.4	0.7	0.12	--	--	2.3
As	0.001	0.002	0.0015	--	0.004	--	--	--	0.0
B	1.6	1.8	1.7	--	--	<.1	0.8	1.0	2.0
Cd	0.0	0.0	0.0	--	<.001	<.001	--	--	--
Cu	0.001	0.001	0.001	0.32	--	<.01	--	--	0.003
Fe	0.03	0.02	0.015	2.86	0.54	<.01	--	--	1.5
Mn	0.05	0.16	0.105	--	0.09	<.01	--	--	--
Pb	0.0	0.0	0.0	0.0	<.005	<.05	--	--	--

* Data obtained by the United States Geological Survey, Helena, Montana.
** Data obtained from the Montana Department of Health and Environmental Sciences, Helena, Montana.

Table 14. Selected water quality criteria and standards for drinking water and surface-public supply as compiled by three sources: Public Health Service (PHS), Drinking Water Standards, 1962; National Technical Advisory Committee (NTAC), "Surface Water Criteria for Public Supplies" in Water Quality Criteria; and the Environmental Protection Agency (EPA), "Public Water Supplies" in Water Quality Criteria, 1972. Concentrations in mg/l unless otherwise specified; fecal coliforms given as the number per 100 ml.

	PHS		NTAC		EPA
Constituent	(a) Standard	(b) Rejection	Permissible Criteria	Desirable Criteria	Recommendation
Ammonia-N	--	--	0.5	<.01	0.5
Arsenic*	0.01	0.05	0.05	absent	0.1
Barium*	--	1.0	1.0	absent	1.0
Boron*	--	--	1.0	absent	--
Cadmium*	--	0.01	0.01	absent	0.01
Chloride*	250	--	250	<25	250
Chromium*	--	0.05	0.05	absent	0.05
Copper*	1.0	--	1.0	near zero	1.0
Dissolved Solids*	500	--	500	<200	--
Fecal Coliforms	(e)	(e)	2000	<20	2000
Iron	0.3	--	0.3	near zero	0.3
Lead*	--	0.05	0.05	absent	0.05
Manganese*	0.05	--	0.05	absent	0.05
Mercury*	--	--	--	--	0.002
Nitrate* (c)	45	--	--	--	--
Nitrate-N* (c)	10.2	--	--	--	10
NO_3+NO_2-N* (c)	--	--	10.0	near zero	--
Nitrite-N* (c)	--	--	--	--	1.0
Oxygen	--	--	>3	saturated	--
pH	--	--	6.0-8.5	--	5.0-9.0
Phenols	0.001	--	0.001	absent	0.001
Selenium*	--	0.01	0.01	absent	0.01
Silver*	--	0.05	0.05	absent	--
Sulfate*	250	--	250	<50	250
Turbidity (JTU)	5	--	75	near zero	--
Zinc*	5.0	--	5.0	near zero	5.0
Fluoride: *(d)					
Upper Limit	1.5-1.7	2.2-2.4			2.2-2.4
Optimum	1.1-1.2	--	(same)		--
Control Limits	0.8-1.7	--			--

(a)--These chemical substances should not be present in water supplies in excess of the listed concentrations where other suitable supplies are or can be made available.

(b)--The presence of these substances in excess of the listed concentrations constitutes grounds for the rejection of the supply.

*--Treatment, defined as coagulation, sedimentation, rapid sand filtration, and chlorination, has little effect on these constituents.

(c)--Adverse physiological effects on infants in extremely high concentrations.

(d)--Criteria varies with the "annual average of maximum daily air temperatures;" with fluoridation, average fluoride levels should be kept within the control limits.

(e)--Criteria varies with the volume of sample, sampling frequency, and analytical technique.

excess of 2000 mg/l; newcomers would find this concentration intolerable although many of the local residents used, and out of necessity, tolerated such mineralized supplies (73). As an added example, although the American Water Works Association considers a water with less than 80 mg/l of hardness (as $CaCO_3$) as "ideal" (10), definite limits for hardness in public water supplies cannot be specified since consumer " . . . sensitivity is often related to the hardness to which the public has become accustomed, and acceptance may be tempered by economic considerations (24)." As a result, although definite concentrational limits can be established for some of the water quality parameters on a physiological-toxicity basis (Table 14), absolute criteria cannot be established for several other constituents such as DS and hardness due to this acceptance variability among groups of people.

Regardless of the use of highly mineralized water by some people, at high enough concentrations, saline waters become completely unsuitable for drinking for physiological and toxicity reasons. This upper limiting value is generally set at about 5,000 mg/l (73). In addition, mild physiological effects are often felt at concentrations much lower than 5,000 mg/l. High DS and sulfate concentrations can produce laxative effects in the casual users of these supplies, but most people become quickly acclimatized to the water (73). Cathartic effects are commonly experienced with water having sulfate concentrations between 600 and 1000 mg/l, particularly if sodium and magnesium are also present in large quantities (52). When sulfate plus magnesium exceed 1,000 mg/l, or if dissolved solids exceed 2,000 mg/l, a majority of the individuals newly using this water have been reported to experience some laxative action (46). Thus, the presence of relatively high levels of ionic constituents in a water is also suggestive of a comparatively poor quality in terms of domestic use.

Biological Criteria--Eutrophication

Lund (1965), through his extensive literature review, concluded that " . . . nitrogen and phosphorus can still be considered as two of the major elements limiting primary production." Gerloff and Skoog (1957) suggested that nitrogen appears to be the more critical factor in the limitation of algal production in natural waters since phosphorus is often stored in excess in algal cells beyond actual need (luxury uptake). But phosphorous concentrations can be very low in some waters, and this parameter may be the more limiting parameter in these particular cases (37). Specific criteria describing the critical levels of nitrogen and phosphorus that are limiting to aquatic systems and that are necessary to promote nuisance algae blooms have not been firmly established due to the complexity of the relationships between these two constituents and between these two constituents and the remaining chemical and physical-biological components of an ecosystem (24). As a result, such criteria, as developed through several investigations, can be somewhat variable. For example, the Environmental Protection Agency (1974B) in their National Water Quality Inventory used 0.1 mg/l of total phosphorus as P, or 0.1 mg/l of orthophosphate as P if total phosphorous data were unavailable, and 0.9 mg/l of nitrite plus nitrate nitrogen as reference criteria for these constituents. However, somewhat lower and more stringent criteria for phosphorus and nitrogen have been adopted by other authorities for use in judging the eutrophic potential of streams.

Phosphorous levels exceeding 0.2 mg/l have produced no problems in some potable supplies (24). In most uncontaminated lakes, phosphorus has been

found in the range of 0.01 to 0.03 mg/l although higher values have been obtained in some nonpolluted cases (59). Federal surveys have indicated that 48% of the aquatic sites samples across the nation had phosphorous concentrations in excess of 0.05 mg/l (29). Reviewing such information, the Environmental Protection Agency has suggested that total phosphorus in concentrations less than 0.05 mg/l would probably restrict nuisance plant growths in flowing waters (24).

In contrast, much higher concentrations of inorganic nitrogen are necessary to initiate algal blooms. Various studies have indicated that excessive growths of plants are avoided when inorganic nitrogen concentrations are less than 0.3 to 0.35 mg/l (39, 47). These two values then--0.05 mg/l for phosphorus and 0.35 mg/l for inorganic nitrogen--can serve as general reference criteria for the nitrogen and phosphorous species in waters of the Poplar Basin. That is, streams and lentic systems in the basin with total phosphorus-P or orthophosphate-P and/or inorganic nitrogen concentrations less than 0.05 mg/l and 0.35 mg/l, respectively, might be judged as non-eutrophic or oligotrophic with some degree of reliability. Such judgements are most valid when total phosphorous data are available and if ammonia-nitrogen data are also at hand in addition to that for nitrite plus nitrate. In turn, waters with phosphorous and inorganic nitrogen concentrations in excess of 0.1 mg/l and 0.9 mg/l can be judged as eutrophic with a high level of certainty. Intermediate concentrations of phosphorus and nitrogen (i.e., between 0.05 to 0.10 mg/l and between 0.35 to 0.90 mg/l, respectively) are suggestive of potentially eutrophic waters but with a lower degree of predictive success.

Biological Criteria--Aquatic Organisms

General aspects.

In addition to nitrogen and phosphorus, a variety of other water quality constituents can also affect aquatic life to varying degrees. Such effects can be positive and beneficial to the biota of an ecosystem under certain concentrations (e.g., availability of essential elements in appropriate concentrations, appropriate temperatures, adequate dissolved oxygen levels, absence of toxic substances, and appropriate salinity and turbidity levels), but they can also be negative and detrimental at other, less optimal levels (e.g., low and limiting concentrations of an essential element, excessively high temperatures, low dissolved oxygen concentrations with high nutrient and organic loads, presence of toxic substances, and high concentrations of salinity and suspended materials). Concern and attention are most commonly directed towards the detrimental influences of the various parameters when their concentrations become too high or too low in an aquatic system. This can be viewed from the standpoint of toxic-lethal or depressing effects on individual organisms, or it can be viewed in the larger sense of reducing the biomass or number of individuals and species in a community (thereby altering its diversity and structure) and of lowering its primary and secondary productivity. In this inventory, the potential detrimental effects of particular water quality parameters will be given primary consideration, and these effects will be generally viewed from an autecological basis.

A list of such affecting parameters would be quite extensive. It would include the more obvious and "common" parameters found in relatively high levels in water, such as oxygen, temperature, pH, salinity, a few of the common

constituents, turbidity, and suspended sediment, but the list would also include the trace elements, critical nutrients, and toxic substances, such as the pesticides and heavy metals, which are found in intermediate or relatively low concentrations. Reference criteria for dissolved oxygen, pH, and temperature in Montana's B-D_2 streams, including the Poplar River, have been described previously (Table 7). The range of pH recommended for these streams is similar to that described by the National Committee on Water Quality Criteria as necessary to afford a moderate to high level of protection for a body of water (24). The criteria for dissolved oxygen is similar to that recommended by Ellis (1944) for a viable and mixed, warm water biota. Salvato (1958) points out that " . . . it is preferable for dissolved oxygen content to exceed 2.5 to 3.0 mg/l to avoid secondary tastes and odors from developing and to support fish life. Game fish require a dissolved oxygen of at least 5.0 mg/l to reproduce, and either die off or migrate when dissolved oxygen falls below 3.0 mg/l." Thus, the limits of pH, temperature, and oxygen specified in Montana's "Water Quality Standards (44)" might be viewed as defining a set of extreme values for these variables outside of which the B-D_2 class of aquatic biota might not be expected to experience much success due to environmental degradation. (Might it be reasonable to vaguely refer to Hutchinson's (1957) niche hypothesis at this point?)

Similar to pH, most of the trace elements can also affect aquatic life, but these constituents are often difficult to assess in a general sense since their effects can vary between individual organisms and species and can be dependent upon the concentrations of other chemical constituents in a water. For example, the magnitude of a trace element effect often depends upon the hardness of a water, and two of these constituents can often act in concert to synergistically influence aquatic organisms to a greater degree than either alone. As a result, such factors as acclimatization and antagonistic-synergistic relationships would have to be considered for a complete discussion of any one of these parameters in any aquatic system. However, the Committee on Water Quality Criteria has established general limits for some of these parameters in terms of the maximum concentrations that can be present without experiencing degradatory effects in a large proportion of the cases (24). But lower levels might be desirable in specific instances. The general recommendations of this committee plus those from two other references (41, 68) are summarized in Table 15.

Since freshwater reference values are not available for some of the trace elements, the marine or seawater criteria for these particular constituents have been included in Table 15. These are probably not directly applicable to the freshwater biota per se, but they do provide some idea of the types of concentrational levels that might be required to impact a freshwater system. Although not ideal, these marine criteria may be of some value in this regard.

With one exception, the values listed in Table 15 are presented as the dissolved concentrations of an element rather than its total recoverable (TR) form. As a result, the TR data are not directly applicable to the table. Fortunately, considerable quantities of dissolved trace element data are available for the Poplar Basin for reference purposes. Of course, if the TR concentrations of an element are below the listed critical value, then adverse effects would not be expected from that constituent since dissolved concentrations are typically less than those obtained from the TR analysis. But if TR concentrations are higher than the reference criteria, then no straightforward interpretations can be made. However, some data are available from the Poplar drain-

Table 15. Recommended maximum concentrations of trace elements for freshwater aquatic life and for marine aquatic life. (The first of two pages.)

Parameter	Reference Concentrations and Comments
Al	--0.1 mg/l (B); >1.5 mg/l hazard, <0.2 mg/l minimal risk (C).
Ag	-->.005 mg/l hazard, <.001 mg/l minimal risk (C).
As	--1.0 mg/l (A); >.05 mg/l hazard, <.01 mg/l minimal risk (C); arsenic tends to be concentrated by aquatic organisms.
B	-->5.0 mg/l hazard, <5.0 mg/l minimal risk (C).
Ba	--5.0 mg/l (tentative)(A); >1.0 mg/l hazard, <.5 mg/l minimal risk (C); barium tends to be concentrated by aquatic organisms.
Be	-->1.0 mg/l hazard, <0.1 mg/l minimal risk (C); based on data from hard freshwater.
Cd	--0.03 mg/l if hardness >100 mg/l as $CaCO_3$, 0.004 mg/l if hardness <100 mg/l (B); >.01 mg/l hazard, <.2 ug/l minimal risk (C); synergistic with copper and zinc.
Co	--about 1.0 mg/l (tentative) (A).
Cr	--0.05 mg/l (A,B); >.1 mg/l hazard, <.05 mg/l minimal risk (C); particularly toxic to lower forms of aquatic life--accumulates at all trophic levels.
Cu	--0.02 mg/l freshwater, 0.05 mg/l seawater (A); >.05 mg/l hazard, <.01 mg/l minimal risk (C).
Cyanide	--0.005 mg/l (B); >0.01 mg/l hazard, <.005 mg/l minimal risk (C).
F	--1.5 mg/l (A); >1.5 mg/l hazard, <.5 mg/l minimal risk (C).
Fe	--<.2 mg/l (A); >.3 mg/l hazard, <.05 mg/l minimal risk (C).
Total Hg	--0.2 ug/l (grab sample), 0.05 ug/l (average)(B); >.1 ug/l hazard (C).
Mn	--1.0 mg/l (A); >.1 mg/l hazard, <.02 mg/l minimal risk (C); manganese tends to be concentrated by aquatic organisms.
NH_3 (unionized)	--0.02 mg/l (B); >0.4 mg/l hazard, <.01 mg/l minimal risk (C).
Ni	-->.1 mg/l hazard, <.002 mg/l minimal risk (C).
Pb	--<.1 mg/l (A); 0.03 mg/l (B); >.05 mg/l hazard, <.01 mg/l minimal risk (C).

Table 15. Continued.

Parameter	Reference Concentrations and Comments

Phenols--0.2 mg/l (A); 0.1 mg/l (B); 0.02 mg/l to 0.15 mg/l, potential tainting of fish flesh (B); 0.001 mg/l reference criteria (D).

Se-->.01 mg/l hazard, <.005 mg/l minimal risk (C).

Zn-->.1 mg/l hazard, <.02 mg/l minimal risk (C).

(A) From McKee and Wolf (1963), "Potential Pollutants" in Water Quality Criteria.

(B) From Environmental Protection Agency (Committee on Water Quality Criteria, Environmental Studies Board) (1973), "Freshwater Aquatic Life and Wildlife" in Water Quality Criteria, 1972.

(C) From Environmental Protection Agency (Committee on Water Quality Criteria, Environmental Studies Board) (1973), "Marine Aquatic Life and Wildlife" in Water Quality Criteria, 1972.

(D) From Environmental Protection Agency (1974), National Water Quality Inventory.

age which can be used to provide a superficial insight into the dissolved (D)-TR relationships of the region.

With reference to iron, its median TR concentrations were found to be typically greater than 4.0-times its median dissolved levels in 89% of the cases, and 2.5-times higher in 96% of the cases. For magnesium, this TR/D ratio was greater than 3.99 in 88% of the instances and greater than 2.0 in all of the data sets. The TR/D factor for aluminum was greater than 15 in all cases. For As, Cu, Mo, Ni, V, and Zn, median TR levels were typically more than two-times higher than the median dissolved concentrations in 78% of the statistical summaries. As a result, if the quotient of the median TR concentration of these constituents divided by the corresponding reference criteria is less than the appropriate factor listed above, then the median of the dissolved form of the trace element most likely lies below the element's reference level in a fairly large percentage of the analyses. As a generalization, if TR levels are less than two-times the reference criteria, then no adverse impacts might be expected from most of the constituents. One exception would include lithium, for example, whose TR and dissolved concentrations appear to be closely equal, i.e., TR/D = 0.73 to 1.43. For many of the trace elements, therefore, if dissolved data are unavailable, some general interpretations might still be made with the TR data as indicated by the above discussion.

Fishery aspects.

If various "field" parameters such as dissolved oxygen, pH, and temperature are at adequate levels for a cold or warm water fishery, then suspended sediment-turbidity and salinity (as described by the dissolved solids or specific conductance) are commonly viewed as the major water quality features controlling the quality of these freshwater fisheries. This, of course, also assumes that the various trace elements are not adversely affecting these organsims. The critical limits of these "field" parameters for B-D_2 streams and those for the trace elements have been noted previously. In the case of suspended sediment, the European Inland Advisory Commission (1965) and the Committee on Water Quality Criteria (24) came to the following conclusions concerning this parameter:

1. there is no evidence that concentrations of suspended solids less than 25 mg/l have any harmful effects on fisheries (a high level of protection at 25 mg/l);

2. it should usually be possible to maintain good or moderate fisheries in waters that normally contain 25 to 80 mg/l suspended solids; other factors being equal, however, the yield of fish from such waters might be somewhat lower than from those in the preceding category (a moderate level of protection at 80 mg/l);

3. waters normally containing from 80 to 400 mg/l suspended solids are unlikely to support good freshwater fisheries, although fisheries may sometimes be found at lower concentrations within this range (a low level of protection at 400 mg/l);

4. only poor fisheries are likely to be found in waters that contain more than 400 mg/l suspended solids (a very low level of protection over 400 mg/l).

These conclusions form the basis of a reference system for this important variable.

If suspended sediment data are unavailable for a stream location, or relatively scarce, the above listed limits for this variable can be described in terms of turbidity with a fair degree of reliability by using equations developed by the WQB for the Yellowstone River drainage (unpublished data). This relationship between suspended sediment (S) and turbidity (T) can be summarized as follows:

$T = 0.37S + 1.0$, if $S < 56$ mg/l ($r = 0.95$); and
$T = 0.20S + 9.0$, if $S > 56$ mg/l ($r = 0.98$).

This conversion and the summary from the European Inland Fisheries Advisory Commission (1965) produces the reference system for these two variables that is summarized in Table 16. As noted, this fishery classification system assumes that other water quality factors, including salinity, are not limiting.

Since fish can tolerate relatively high suspended sediment or turbidity levels for certain periods of time (74), the reference levels for this variable in Table 16 imply a relatively constant exposure to the various class concentration ranges in order to invoke the associated type of fishery (i.e., excellent, moderate, poor, and so on). Thus, the median suspended sediment values (or turbidity values) that were obtained at each stream location during the low flow seasons will be utilized in relation to this classification system since this statistic is probably most representative of the "typical" concentration in the stream; i.e., that suspended sediment level that is most commonly expressed through the year and observed through a largest proportion of the days. However, " . . . although several thousand parts per million suspended solids may not kill a fish during several hours or days of exposure, temporary high concentrations should be prevented in rivers where good fisheries are to be maintained. The spawning grounds of most fish should be kept as free as possible from finely divided solids (24)." As a result, some consideration should also be given to the extra-median concentrations of sediment.

For the most part, waters with median levels of suspended solids and turbidity of 15 mg/l and 5 JTU and occasional extremes of 100 mg/l and 30 JTU would be expected to provide conditions for a better fishery than a stream with medians of 70 mg/l and 23 JTU and occasional extremes of 150 mg/l and 40 JTU. In turn, waters with medians of 100 mg/l and 30 JTU should be more productive than streams with medians of 300 mg/l and 70 JTU and similar maximum concentrations. In addition, a stream with generally low median suspended sediment and turbidity levels (e.g., <100 mg/l and <30 JTU) but with relatively high and temporary concentrations of sediment at certain periods of the year (e.g., 400 mg/l and 91 JTU) might be able to successfully support a migratory or stocked fishery in its waters, but it might not be able to sustain a resident (breeding) population since the pulse of sediment could eliminate the fishes' spawning grounds. Thus, the median values of suspended sediment (or turbidity) during the high flow periods and the maximum levels that are obtained through the year will also be considered in this inventory when evaluating the quality of the Poplar fishery at each stream location.

In most cases, reference criteria for the common ions are not available for aquatic organisms. For example, the National Committee on Water Quality

Table 16. Fishery classification and reference system for suspended sediment and salinity. Data in set I were taken from the European Inland Fisheries Advisory Commission (1965), and the data in set II were compiled from a variety of sources including Ellis (1944), Mace (1953), and Peterka (1972).

I. Suspended Sediment

Suspended Sediment Range (mg/l)	Class of Fishery	Corresponding Turbidity Range (JTU)
<25	Excellent	<8
25 to 80	Good to Moderate	8 to 26
80 to 400	Fair to Poor	26 to 91
>400	Very Poor	>91

II. Salinity

Salinity Range as Dissolved Solids (mg/l)	Salinity Range as Specific Conductance (umhos per cm at 25C)	Type of Fishery	Class of Fishery
<340	<500	Resident	Excellent
340 to 870	500 to 1300	Resident	Generally Excellent
870 to 1350	1300 to 2000	Resident	Good to Fair
1350 to 2700	2000 to 4000	Resident	Fair to Poor
<2700	<4000	Migratory	Generally Good
2700 to 3350	4000 to 5000	Resident	Poor
2700 to 3350	4000 to 5000	Migratory	Fair to Poor
>3350	>5000	Resident	Very Poor
>3350	>5000	Migratory	Very Poor

Criteria in its considerations of "Freshwater Aquatic Life and Wildlife" did not list any specific reference values for such chemical constituents as calcium, magnesium, sodium, potassium, sulfate, and chloride. But these constituents are extremely important in an additive sense in forming the salinity characteristics of a water, and one of the main effects of high ionic concentrations, and thereby of high salinity levels, is that of osmotic stress. As a result, the " . . . quantity and quality of dissolved solids are major factors in determining the variety and abundance of plants and animals in an aquatic system . . . . A major change in the quantity of composition of total dissolved solids changes the structure and function of aquatic ecosystems . . ."; however, " . . . such changes are difficult to predict (24)." Hart, et al (1945) has observed that only 5% of the inland waters supporting a mixed biota had salinities in excess of 400 mg/l (in excess of about 600 umhos as specific conductance), whereas 10% of these waters had dissolved solids concentrations that were greater than 400 mg/l. This discrepancy between percentages is illustrative of a "breaking point" in terms of the lowered success of freshwater communities when salinities exceed the 400 mg/l level.

Ellis (1936, 1944) and Ellis et al (1946) were among the first workers to propose water quality criteria that would insure the viability of a good, mixed fish fauna in freshwater systems. The criteria that were developed by these investigators have been summarized in detail by McKee and Wolf (1963). Of the parameters considered, they proposed the following criteria for salinity: specific conductances at 150 umhos to 500 umhos as a general category for all waters, between 100 mg/l and 340 mg/l of dissolved solids (non-saline), with a maximum level of 1000 umhos to 2000 umhos permissible in streams of western alkaline areas such as the Poplar River (670 mg/l to 1350 mg/l, non-saline to slightly saline). Although Mace (1953) reported that the upper limit of osmotic stress could range between 5,000 and 10,000 mg/l of dissolved solids for freshwater fish depending upon species and preconditioning (moderately saline waters), Peterka (1972) found an absence of walleye hatch at specific conductances greater than 4,000 umhos (greater than 2,700 mg/l), and the hatch for northern pike was found to be very poor at this same salinity level. In contrast, the development of fathead minnows at salinities of 4,000 umhos was found to be comparatively good as indicated by the following results (51):

Abnormality in sac fly	Specific conductance (umhos)
37%	500
50%	1,300
53%	4,000
87%	6,000
100%	12,000

Nevertheless, the development of these minnows was much more successful in waters with specific conductances less than 1300 umhos, and no depressions of the walleye and northern pike hatches were observed at this same value (51). Thus, although freshwater fish might be able to tolerate the osmotic stress of moderately saline waters (38), at least for short periods of time, Peterka's (1972) findings indicate that many of these fish would not be able to propagate themselves when placed under these conditions.

Based upon the results of these various investigations, general reference criteria for salinity can also be established in relation to the freshwater

fisheries. At the first level, waters having specific conductances and dissolved solids less than 500 umhos and 340 mg/l might be judged as good to excellent for all fisheries. Between 500 umhos and 2000 umhos and between 340 mg/l and 1350 mg/l, waters would be suitable for those fisheries that are located primarily in the western, alkaline portions of the United States, and these waters would be best suited to those fish species that can become readily acclimatized to the higher salinity levels. However, some distinct reductions in hatching and developmental success might be expected from about 1300 umhos (about 870 mg/l) to 2000 umhos. At another level, greater losses in hatching and fry development could occur above 2000 umhos, and this could seriously degrade a fish population. Above 4000 umhos (2700 mg/l), a resident or breeding and successfully rearing population of fish would not be expected in most instances, even though the adult and migratory or stocked fish can probably withstand this level of salinity for fairly long periods of time. Waters having specific conductances in excess of 5000 umhos (3350 mg/l) are probably approaching the upper physiological limits for many of the freshwater species of fish, and only transient and extremely depaupered fish populations of poor quality might be expected to occur under such conditions. These various reference values for salinity have been formalized for this review, and these are listed in Table 16.

SITE INVENTORY--INSTREAM SPECIFIC WATER QUALITY ASSESSMENTS

MAIN INVENTORY STREAM--EAST POPLAR RIVER IN MONTANA

General Considerations and Sampling Site Locations

Of the various streams and reaches in the Poplar River drainage, the East Poplar River will be most directly affected by the Coronach electrical generation facilities. As a result, numerous sampling efforts have been directed to this stream in recent years in order to afford the capabilities for describing its quality characteristics for developmental, modeling, and general baseline monitoring purposes. Thus, a great deal of water quality data is available for the East Poplar at the present time, and this is most distinct for the international boundary location where a variety of United States and Canadian entities have initiated water sampling programs on the stream (Table 5). As a result, the most valid water quality descriptions can now be made for the more

eastern segments of the Poplar system. However, some water quality data are also available for the Poplar River mainstem and for the western tributaries of the Poplar drainage.

The main focus of this inventory will be directed to the East Poplar River because of the Coronach-related impacts that might be adversely affecting this stream in the very near future. As a result, the water quality discussion for this particular river will be fairly extensive. However, the downstream reaches of the Poplar River could also be directly affected by this development to some extent as the impacts initiated in the East Poplar are carried downstream into Montana. Thus, the lower reaches of the mainstem will also be considered in this review. In turn, the magnitude of these downstream effects will be dependent upon the quantity and quality of waters in various groundwater and tributary inputs to the river below the Coronach reservoir and the associated dilution capacities of these input waters. Therefore, considerations of these tributary streams, such as the Middle and West Forks, should also be included into any Coronach assessments, particularly in view of the fact that these waters might be transferred between drainages for developmental purposes in order to supplement the quantities that are available from the East Poplar. Due to these factors, these tributaries will also be considered to some extent in this report. But the quality discussions for these tributaries and the Poplar mainstem will be less extensive and generally referenced to that for the East Poplar, and the special or unique features of these non-East Fork waters will be primarily stressed in their reviews.

The United States Geological Survey (USGS) is now sampling the East Poplar River at the international boundary on a monthly basis for numerous water quality parameters. This USGS site is located about 14 miles (23 kilometers) north of Scobey, Montana and 20 miles (32 kilometers) above the river's mouth at T.01, R.26W, 01C (Saskatchewan designation), or approximately at T.37N, R.48E, 04BB-05AA (Montana designation), in conjunction with their flow gaging site (72). (See Appendix I for the method of describing the geographical position of these sampling sites.) The USGS also maintains a flow gaging and water quality sampling station on the lower reach of the East Poplar near Scobey. This site is located in Daniels County at T.36N, R.48E, 27BA near the Highway 13 bridge about 2.5 miles (4 kilometers) from the stream's mouth (72). Quality samples are also being collected from this location on a monthly basis. In addition, the upper reach of the East Poplar in Saskatchewan and a major tributary (Girard Creek) to the river in this region have been extensively sampled by various Canadian e..ities (Table 5). These stations are located near Coronach, Saskatchewan in close proximity to the generating facilities that are now under construction near this community. Water quality data from these locations were also summarized for this review.

The USGS is also sampling both the Middle and the West Forks of the Poplar River at two locations on a monthly basis--at two international boundary stations and at two downstream sites. The border station on the Middle Fork is located about 18.5 miles (30 kilometers) northwest of Scobey in T.37N, R.46E, 06D in conjunction with an international flow gaging station (72). The downstream site on the Middle Fork is located in approximately T.36N, R.47E, 13DA about 6 miles (9.5 kilometers) northwest of Scobey and less than 8 miles (13 kilometers) from the stream's confluence with the East Poplar River (55). Both of these stations are found in Daniels County. The border station on the West Fork is located about 11 miles (18 kilometers) north of Opheim, Montana at ap-

proximately T.36N, R.41E, 05B in Valley County. The USGS has also sampled two downstream sites on the West Fork, one near Four Buttes in Daniels County, and one located further downstream near Bredette in Roosevelt County. The first station was in operation between August, 1975 and May, 1976 and has since been discontinued, but monthly water quality samples are now being collected from the second site starting in July of 1976. This active station on the West Fork is located in approximately T.32N, R.48E, 01CC about 6 miles (9.5 kilometers) upstream from the Fork's confluence with the main Poplar (55). The quality data from the two downstream stations on the West Fork were combined for the statistical summaries of this review.

In addition to sampling the three forks or upper reaches of the Poplar River, the USGS is also collecting samples from two sites on the Poplar mainstem. One station is found in the middle reach of the river near Bredette in Roosevelt County between the confluences of the Middle and West Forks (55). This site is located in approximately T.32N, R.49E, 04CC and less than 7 miles (11 kilometers) above the West Fork confluence. The second mainstem station is found on the lower river below the confluence of the West Fork. This site is located in Roosevelt County about 4 miles (6.5 kilometers) north of Poplar, Montana in T.28N, R.51E, 19AA and about 11 miles (18 kilometers) upstream from the confluence of the Poplar and Missouri Rivers (72). Water quality samples are also being collected from these mainstem locations on a monthly basis, and the lower quality site is being operated in conjunction with a continuous recording, flow gaging station.

As summarized in Table 5, some water quality data in addition to that collected by the USGS are available from other agencies for the same stream locations described above, or for closely associated sites. Data from these other agencies that corresponded to a particular USGS station were combined with the USGS data from that location for the statistical summaries. The non-USGS data that were collected from locations apart from the USGS sampling sites were combined, for summary purposes, with the USGS data that were obtained from the closest USGS site. Water quality data from the various Canadian agencies were included into these summaries as appropriate. In addition, water analyses are available for nine miscellaneous streams and sampling locations in the Poplar drainage, as listed in Table 5, and these data have also been summarized for this inventory.

East Poplar River at the International Boundary

Field parameters and dissolved solids.

Statistical summaries of samples analyzed for the various "field" parameters are presented in Table 17 for the East Poplar River at the international boundary. On the basis of discharge, this river appears to be a relatively small stream at the United States-Canadian border with median low flows at the time of quality sampling approaching only 0.7 cfs during the winter months and 3.3 cfs during the warm weather period. Mean flows determined from the 1931 to 1974 period of record (55) were found to be roughly similar for each season to the means that were obtained in conjunction with the quality sampling after a weighting of the latter by sample numbers; an average discrepancy of 29% was obtained between the two sets of discharge data. Thus, the quality data in

Table 17. Summary of chemical analyses of water collected from the East Poplar River at the international boundary--field parameters and dissolved solids.

Stat	Flow	Temp	pH	Clr	Turb	TSS	SC	DS	DO	%Sat	BOD	TC	FC
November-February													
N.	16	16	21	17	24	7	25	25	15	10	5	8	8
Min	0.34	0.0	7.0	<5	1.1	2.	995	700	0.8	6	0.5	<1	<1
Max	5.5	5.	8.30	50	11.	24.	1850	1260	12.8	102	2.2	230	40
Mean	1.65	0.75	7.58	<11	4.5	12.1	1338	955	6.0	47	1.2	<58	<14
Med	0.69	0.5	7.5	5	4.1	10.	1380	927	5.5	47	1.1	39	<2
March-May (low flows)													
N.	27	10	26	21	25	6	27	24	9	7	5	6	6
Min	1.4	0.2	7.5	<5	2.5	15.	410	291	4.4	33	1.6	<1	<1
Max	19.	21.5	8.66	80	27.	40.	1450	1145	12.8	114	2.4	90	90
Mean	7.8	8.4	8.08	<16	9.6	25.6	1074	784	8.7	86	2.1	36	<28
Med	7.4	5.0	8.17	6	8.9	21.8	1100	850	8.8	98	2.2	16	<23
March-May (high flows)													
N.	16	7	16	10	13	5	16	15	7	3	3	2	2
Min	20E.	0.0	7.70	25	5	9.2	295	97	4.4	50	2.0	<10	<10
Max	76.	16.5	8.8	80	180	36.	1325	1116	11.4	102	3.3	70	40
Mean	41.4	10.6	8.08	54	29	20.8	673	425	8.8	84	2.7	<40	<25
Med	37.5	14.5	7.98	55	15	18.	618	405	9.5	99	2.8	<40	<25
March-May (extreme high flows)													
N.	10	1	10	9	10	0	10	10	1	1	1	0	0
Min	101	--	7.20	<5	5.6	--	115	102	--	--	--	--	--
Max	600	--	8.57	100	180.	--	1050	735	--	--	--	--	--
Mean	336	--	7.85	60	75.2	--	358	245	--	--	--	--	--
Med	330	4.0	7.75	65	55.5	--	324	191	9.0	75	3.2	--	--
June-October (low flows)													
N.	43	19	43	32	39	10	42	42	18	10	6	4	6
Min	0.39	5.0	7.0	<5	1.3	10.	830	597	4.5	82	1.6	<10	0
Max	19.	22.6	9.0	60	60.	90.	2300	2252	12.3	136	5.6	430	430
Mean	4.9	15.9	8.38	15	8.1	38.6	1369	940	9.1	98	3.7	<125	105
Med	3.3	16.0	8.39	10	4.6	30.	1245	826	9.4	95	3.7	31	54
June-October (high flows)													
N.	7	7	7	1	6	4	7	6	6	4	3	0	0
Min	23.	17.5	6.5	--	4.	12	1240	891	5.0	60	1.9	--	--
Max	140.	24.5	9.1	--	55.	20	2410	1790	8.2	93	2.5	--	--
Mean	60.6	21.8	8.49	--	20.8	16	1850	1366	5.9	76	2.2	--	--
Med	52.	21.5	8.76	60	15.	16	2056	1454	5.2	70	2.2	--	--

Table 17 appears to be fairly representative of the annual flow regime of the stream. Similar to the flow data for the period of record, relatively high discharges were observed during the spring runoff period of March-May, and high flows were occasionally observed during the warm weather months. However, these pulses of high flow were relatively short-lived when compared to the duration of the low flow periods. This feature can be illustrated by determining the percentage of days that had flows falling into each of the six season-flow classes; such an analysis was based on the twelve years of record for water years 1964 to 1975 (72, 93), and the results are summarized below:

November-February	March-May	March-May	March-May	June-October	June-October
			extreme		
low flows (<20 cfs)	low flows (<20 cfs)	high flows (20-100 cfs)	high flows (>100 cfs)	low flows (<20 cfs)	high flows (>19.9 cfs)
about 32.9%	17.6%	5.0%	2.6%	40.4%	1.5%

As indicated above, high flow events in the East Poplar River would be expected to occupy only about 9% of a "typical" year.

The discharge analysis described above and the specific conductance data in Table 17 indicate that the qualities of water that are obtained during the low flow periods probably have a greater, overall effect on aquatic life than those obtained during the high flow phase. This is due to the higher concentrations of many variables at low flows coupled with the greater duration of these low discharge events; that is, aquatic organisms are exposed to the low flow qualities of the East Poplar River for about 91% of the time. To account for this duration aspect, the above listed percentages can be utilized to calculate a yearly median or mean concentration of a variable that is weighted in relation to this duration feature. This weighted statistic, in turn, might be viewed as the yearlong or typical exposure concentration of any variable, and it can be used to assess the potential effect of the parameter on aquatic life.

In the case of turbidity, for example, the yearly weighted median for this variable was calculated at 7.2 JTU for the East Poplar River at the international boundary, and the weighted median sediment concentration was estimated as 26.4 mg/l for this location. According to the classification system of the European Inland Fisheries Advisory Commission (1965), the median low flow levels of turbidity and suspended sediment at this sampling station were of small enough quantities to be suggestive of a good to excellent class of fishery (Table 16), and the yearly weighted medians for these two variables are in accord with this observation. Although suspended sediment-turbidity levels were observed to increase in conjunction with increases in flow, as is typical of many streams, the median levels during the high flow periods and the maximum concentrations of these variables were not of sufficient magnitude nor duration to be indicative of a fishery degradation. Although mean suspended sediment and turbidity levels were generally greater in any season than the median values, the mean levels of these variables are also suggestive of a good fishery in the upper reaches of the East Poplar River. On the basis of the yearly weighted medians, an increase in suspended sediment concentrations on the order of ten-times over those listed in Table 17 would have to be affected in order to significantly degrade the resident fishery, if present, to a "poor" classification.

In contrast to suspended sediment, dissolved solids (DS) concentrations and specific conductances (SC) generally tended to decline in the East Poplar

River during high flow events. This is a common feature of many rivers, although this relationship is often not well-defined in the smaller prairie streams of Montana (86). This lack of definition is also evident in the East Poplar at the international boundary to some extent through the high DS-SC values that were obtained during the high flow, June-October period (Table 17). Since the DS-SC levels of the samples were typically highest when collected during periods of reduced flows, the yearly weighted medians and means for these variables, in contrast to those for turbidity and suspended sediment, were found to be comparatively high and generally similar to the low flow values; these statistics for DS-SC equalled 836 mg/l and 879 mg/l, and 1221 umhos and 1253 umhos respectively. Even though high DS-SC levels in excess of 1350 mg/l and 2000 umhos were occasionally obtained at the border station, suggestive of a poor resident fishery, these yearly weighted statistics point to a "generally excellent" class of fishery (Table 16) in the upper segment of the East Poplar River, given no other limiting factors. However, this fishery designation is much more marginal in character than the "good to excellent" classification that was made on the basis of suspended sediment; that is, only a three-fold increase in DS-SC could degrade the waters of the stream to a poor quality from a biotic point of view in contrast to the ten-fold increase that would be required for suspended sediment. In turn, an overall increase in DS-SC of about 1.6-times relative to the medians and means in Table 17 could reduce the quality of waters in the upper East Poplar to those of a fair fishery. Thus Needham's (1976) characterization of the Poplar drainage as a borderline, prairie fishery apparently has some validity in terms of the stream's quality data.

Of the various "field" parameters summarized in Table 17, temperature, pH, and dissolved oxygen (DO) probably have a greater capacity for influencing the stream biota than either salinity or suspended materials since the concentrations of these first three variables have tended to approach critical levels on occasion during the past few years. Minimum temperatures during the low flow winter season, and extending into March and possibly April, generally approached 0.0 C in the East Poplar during a time when the Poplar system is typically covered by several feet of ice throughout its length in Montana. But such low minimum temperatures are common in most of Montana's streams during these periods of cold weather, and such low temperatures per se are not critical for the aquatic biota when these cold snaps do not last for excessive lengths of time. The marked warming trend of the East Poplar during the spring and summer seasons is probably much more important in a biotic sense with temperatures in the 20 C's common during the warm weather periods.

In many instances, the maximum temperatures recommended for a cold water fishery (Table 7) were exceeded by grab samples collected from East Poplar, border station. Temperature data from the stream as summarized by Aagaard (1969) are in accord with this observation (Table 18). In addition, the USGS has obtained continuous temperature records from the East Poplar for the summer of 1975 (72) during an above average discharge year, and they found that 58% of the days during this period had maximum temperatures in excess of the cold water criteria. In many cases, the lethal tolerance limits for the juvenile stage of cold water species such as rainbow, brown, and brook trout, set at 26.5 C (78), 22-24 C (82), and 24-26 C (84) respectively, were exceeded by the East Poplar River. In contrast, only a small percentage of the temperature readings obtained by these three sources were in excess of the criteria for a warm water fishery (Table 18), and only in rare cases were the lethal toler-

Table 18. Temperature characteristics of the East Poplar River at the international boundary expressed as the percentage of readings falling within various temperature ranges specified for cold water (19.4C) and warm water (26.7C) fisheries; minimum, maximum, and median values are also listed. Data were taken from (1) Aagaard (1969) and (2) the United States Geological Survey (1975) and from other miscellaneous sources.

Period of Observations	Temperature Range or Statistic	Winter	Runoff	June	July	August	September	October	Warm Weather
Grab sample temperatures:	<19.4C	100%	94%	--	--	--	--	--	58%
May, 1975 to August, 1977	19.4C to 26.7C	0%	6%	--	--	--	--	--	42%
	>26.7C	0%	0%	--	--	--	--	--	0%
	Minimum	0.0C	0.0C	--	--	--	--	--	5.0C
	Maximum	5.C	21.5C	--	--	--	--	--	24.5C
	Median	0.5C	10.3C	--	--	--	--	--	18.5C
	Sample Number	16	18	--	--	--	--	--	26
Grab sample temperatures (1):	<19.4C	100%	99%	56%	13%	9%	75%	100%	41%
March, 1949 to November, 1965	19.4C to 26.7C	0%	1%	44%	88%	91%	25%	0%	59%
	>26.7C	0%	0%	0%	0%	0%	0%	0%	0%
	Minimum	0.0C	0.0C	15.0%	14.4C	15.0C	10.0C	4.4C	4.4C
	Maximum	5.6C	22.2C	22.8C	26.1C	26.7C	20.6C	12.8C	26.7C
	Median	3.3C	1.1C	18.9C	22.2C	21.7C	13.9C	10.0C	20.0C
	Sample Number	7	70	9	8	11	4	5	37
Continuous daily records (2):									
June, 1975 to September, 1975									
Maximum temperatures	<19.4C	--	--	36%	0%	45%	100%	--	42%
	19.4C to 26.7C	--	--	64%	84%	55%	0%	--	53%
	>26.7C	--	--	0%	16%	0%	0%	--	5%
	Minimum	--	--	16.5C	22.0C	14.0C	8.5C	--	8.5C
	Maximum	--	--	25.5C	29.5C	23.0C	17.5C	--	29.5C
	Median	--	--	21.8C	25.5C	19.5C	14.8C	--	20.5C
	Sample Number	--	--	14	31	31	22	--	98
Minimum temperatures	<19.4C	--	--	86%	3%	97%	100%	--	66%
	19.4C to 26.7C	--	--	14%	97%	3%	0%	--	34%
	>26.7C	--	--	0%	0%	0%	0%	--	0%
	Minimum	--	--	13.5C	19.0C	12.0C	7.0C	--	7.0C
	Maximum	--	--	21.0C	25.0C	19.5C	15.5C	--	25.0C
	Median	--	--	17.3C	21.5C	16.5C	9.5C	--	17.5C
	Sample Number	--	--	14	31	31	22	--	98

ances for warm water species such as northern pike, channel catfish, and fathead minnow, set at 32-33 C (91), 36-38 C (79), and 28-33 C (85) respectively, exceeded by the East Poplar samples. However, the overall median temperature values of the June-October season were generally less than that recommended for a cold water stream, and this dichotomy of maximum versus "typical" temperatures relative to the fishery criteria coincides with Montana's classification of the East Poplar as a $B\text{-}D_2$ or marginal cold water stream. Nevertheless, the temperature data in Tables 17 and 18 indicate that the East Poplar is most probably a warm water stream with the marked success of a propagating cold water fishery highly unlikely in its waters. The various fishery surveys that have been conducted in this drainage should afford more insight into the stream's status in this regard.

Dissolved oxygen concentrations in the upper East Poplar River were relatively high during the low flow, spring and summer seasons with median values very near 100% saturation (Table 17). Although DO levels tended to decline to some degree during the high flow periods, the concentrations of this variable were above the State recommendations for $B\text{-}D_2$ and $B\text{-}D_3$ (5.0 mg/l) streams (44) in 78% and 93%, respectively, of the samples collected during the March through October span. Much more critical to the aquatic biota, however, would be the low concentrations of DO that were obtained during the cold weather season with means and medians well below the recommended levels for $B\text{-}D_2$ waters (Table 7); about 73% of the samples collected during this winter period had DO concentrations less than the State's criteria for a marginal, cold water fishery. Since a lower proportion of the samples had DO levels below the $B\text{-}D_3$ recommendation (47%), on this basis the East Poplar might be best designated as a $B\text{-}D_3$ rather than a $B\text{-}D_2$ water; but the fact that 13% of the winter samples had DO concentrations lower than the critical limiting levels for game fish recommended by Salvato (1958) indicates that the upper East Poplar may be marginal even in this regard. In any event, the low winter DO's are at least suggestive of fish emigrations out of this reach at some points during the November to February period.

The low DO levels in the upper East Poplar during the winter season are probably a reflection of the ice cover that develops on the stream at this time, precluding effective oxygen exchange with the atmosphere and photosynthetic activity. Significant inputs of organic pollution to the stream can probably be eliminated as a causal factor since sample BOD_5 values were relatively low during the entire year. For example, 78% of the samples from the border station had BOD_5 concentrations less than 3.0 mg/l while 87% had BOD_5's less than 4.0 mg/l; furthermore, BOD_5 levels were significantly lower during the winter than the rest of the year. In addition, relatively low fecal and total coliform counts were also obtained from the river with the seasonal means of these variables less than the average count recommended for surface waters by the State of Montana (Table 7). These features are also indicative of the general lack of man-related organic inputs reaching the stream. Thus the winter decline in DO levels is most likely attributable to the natural BOD content of the waters and biotic respiration in the face of a low aeration factor. This observation is supported by the fact that high DO concentrations were obtained in some of the winter samples (approaching 13.0 mg/l), and these were probably collected before the development of ice cover or shortly thereafter before the natural oxygen demand of the system had a chance to lower the DO content of the water to any appreciable degree.

These various observations on DO levels suggest that the East Poplar would probably be very sensitive to any increases in BOD concentrations as a result of man's activities, particularly during the winter season. This should be kept in mind when reviewing the Coronach development in terms of associated population increases and increases in municipal sewage that might conceivably reach the stream. Such occurrences could drastically affect the aquatic biota through a further lowering of critical oxygen availabilities during the cold weather season.

In conjunction with ice cover and the minimum DO levels, values of pH were also found to be relatively low during the winter season in response to the reducing conditions of the stream at this time. Values of pH were also somewhat lower during the spring runoff period than during the warm weather season, but minimum levels were always above the low extreme recommended by the State (Table 7). With the advent of ice-off in the spring and re-aeration, pH then increased significantly through the March-May and summer seasons. This warm weather increase in pH might have been due, in part, to a photosynthetic utilization of bicarbonate ions by photosynthetic organisms with the subsequent release of hydroxide radicals. If this were the case, then the high pH's that were achieved during the summer would be indicative of a fairly productive river. Regardless of the high pH values that were obtained on occasion, only one sample violated the maximum extreme recommended for warm water streams. In contrast, the maximum criteria for cold water or $B\text{-}D_1$ streams (44) (pH = 8.5) was exceeded by 32% of the samples collected from June to October and by 4% of the samples collected during the rest of the year. Thus, the East Poplar River, on the basis of pH, is apparently best classified either as a $B\text{-}D_3$ stream or as a marginal cold water fishery.

Common constituents.

As noted earlier in this report, the method of data separation and organization utilized in this inventory appears to have normalized the water quality data to a considerable degree since the mean and median values of many of the flow-season-parameter data sets are closely similar. This feature can be illustrated by the yearly weighted DS and SC statistics that have been described previously for the East Poplar; in this case, the weighted means and medians are nearly identical, differing by less than 5%. This aspect is also illustrated by the close similarities between means and medians in most of the data sets in Table 19. Such mean-median differences could have been much greater than those shown if these determinations had been made on data that was not initially classified in this manner.

Waters in the East Poplar River at the international boundary were primarily non-saline (58), although slightly saline samples were collected on occasion throughout the year; 18% of the samples obtained from the river would fall into this latter category. In turn, the East Poplar can be classified as having "very hard" waters (10, 19) with relatively high calcium and magnesium concentrations (Table 18). However, many of the high flow samples would be given some lesser "hardness" designation as a result of dilution by non-saline runoff water, and like the case for DS-SC, the concentrations of the various ions were generally inversely related to flow. Regardless of the high calcium and magnesium levels, these cations do not represent the major dissolved constituents of the stream with the East Poplar best described as having a sodium bicarbonate-type of water (Table 19). Calcium and magnesium along with sul-

Table 19. Summary of chemical analyses of water collected from the East Poplar River at the international boundary--common constituents.

Stat	CO_2	HCO_3	CO_3	TA	PA	Cl	SO_4	Ca	Mg	TH	Na	SAR	%Na	K
November-February														
N.	15	16	16	25	16	25	25	25	25	25	25	16	15	25
Min	4.1	575	0.0	448	0.0	3.0	170	41.	35.9	281	128	3.0	45.	6.9
Max	89.	929	0.0	762	0.0	8.0	310	89.	60.	442	290	6.5	63.2	18.
Mean	38.1	717	0.0	593	0.0	5.2	236	72.7	46.0	370	207	4.4	55.3	9.9
Med	37.	695	0.0	568	0.0	4.9	232	73.	47.	377	190	4.1	57.3	8.2
March-May (low flows)														
N.	8	11	11	27	20	27	27	27	27	27	27	22	8	26
Min	3.8	501	0.0	182	0.0	<.3	50	19.	17.	143	43	1.3	43.	7.
Max	35.	695	0.0	570	29.	6.5	270	100.	68.	489	220	5.6	59.	27.
Mean	17.4	595	0.0	440	3.8	3.0	186	59.1	45.5	335	135	3.2	52.5	11.7
Med	18.5	610	0.0	458	0.0	2.7	190	58.	45.	331	125	2.9	53.9	9.9
March-May (high flows)														
N.	3	5	5	14	10	14	14	14	14	14	16	12	3	14
Min	1.0	73	0.0	60	0.0	0.8	20	12.	4.8	50	12	0.7	30.	7.3
Max	2.3	565	2.	463	0.0	23.	250	66.	33.	300	200	5.0	61.5	19.
Mean	1.5	308	0.4	229	0.0	4.7	95	34.0	21.5	174	69	2.1	50.8	12.1
Med	1.6	288	0.0	234	0.0	2.2	86	31.5	22.3	166	60	1.8	61.	13.
March-May (extreme high flows)														
N.	1	1	1	10	9	10	10	10	10	10	10	8	1	10
Min	--	--	--	53	0.0	0.4	12	8.8	4.9	51	3.4	0.2	--	7.5
Max	--	--	--	438	31.	11.	200	64.	41.	328	138.	2.8	--	22.2
Mean	--	--	--	139	3.4	2.8	56	23.1	12.8	110	35.	1.1	--	11.3
Med	4.5	142	0.0	118	0.0	1.1	35	18.5	10.2	89	28.	1.1	42	8.9
June-October (low flows)														
N.	14	16	16	41	31	41	41	43	43	40	43	34	14	40
Min	1.3	553	0.0	347	0.0	<.1	120	13.8	37.	238	103	2.3	45.	7.3
Max	9.1	849	134	920	112	26.	525	64.	74.	385	550	7.7	70.9	67.
Mean	4.4	657	25	510	15	5.3	246	43.0	51.2	316	215	4.3	61.0	14.2
Med	5.0	650	0.0	488	8	3.7	238	43.3	50.	326	173	4.0	61.5	11.5
June-October (high flows)														
N.	4	5	5	5	1	6	6	7	7	6	7	5	5	6
Min	1.1	446	0.0	454	--	2.0	250	26.	35.	210	220	6.2	64.	19.
Max	3.4	771	89	736	--	16.	540	40.	67.	330	465	9.6	71.5	34.
Mean	1.7	640	53	613	--	9.3	390	29.6	52.0	276	337	7.8	67.9	26.2
Med	1.1	710	61	702	61	8.7	390	28.	60.	286	388	7.4	68.	26.

fate represent the secondary ions with potassium and chloride making insignificant contributions to the salinity of the stream. Total alkalinities were typically high, and occasionally high levels of phenolphthalein alkalinity and carbonate were observed during the summer months in the East Poplar in conjunction with the high pH values that were obtained in some of the samples at this time of the year. In general, none of the ionic constituent concentrations appeared to be adequate levels on an individual basis to adversely affect the aquatic biota.

Nutrients and other constituents.

Statistical summaries of the data available for various nitrogen and phosphorous species and for several other major water quality parameters, such as fluoride, iron, and boron, are presented in Table 20 for the East Poplar River. As indicated in this table, fluoride, like potassium and chloride, represents an insignificant ionic constituent of the East Poplar samples. As a result, concentrations of fluoride were well below the critical levels of this variable for freshwater systems (Table 15) in all of the samples. Dissolved iron concentrations were also relatively low throughout the year. Although total recoverable iron levels were comparatively high and tended to increase to some extent with high flow events, probably in association with the greater suspended sediment levels, the dissolved component of this metal was typically below its reference criteria for freshwater aquatic life (Table 15). Only 6% of samples demonstrated dissolved iron concentrations in excess of 0.3 mg/l (hazardous), while 88% had dissolved iron levels less than 0.2 mg/l (minimal risk). In contrast, except for the high flow period, dissolved boron levels were relatively high in the East Poplar in comparison to most of the trace elements such as iron with the yearly weighted mean and median equalling 1.83 and 1.80 mg/l respectively. However, this constituent does not appear to be in adequate concentrations to adversely affect the biota of the stream (Table 15). Wurtz (1945) has observed that a 2000 mg/l solution of boric acid had no toxic effects on rainbow trout and rudd, and this experimental concentration is about two orders of magnitude higher than the maximum level of boron in the East Poplar at the international border.

Silica concentrations were observed to be much higher in the East Poplar River than the case for fluoride, iron, and boron (Table 20), but these silica levels were not excessively high in view of the fact that the median concentrations were either equal to or less than the median value for the nation's surface waters (83). Of some interest are the fairly consistent declines in silica levels that were obtained from the November-January, cold weather period to the June-October, warm weather season. Since diatoms require silica as a structural component of their outer "shells" or frustules, this seasonal decline in the East Poplar may have been related to the utilization of silica by the floral component of periphyton communities in the stream; this decline does not appear to have been due to runoff events. The median concentrations of silica was about 81% lower in the summer during a period of high biological activity than during the winter period of general biotic dormancy. These changes in silica, in turn, correspond to the distinct increases in pH that were obtained in the stream during the summer months, and this feature may also be attributable to the enhanced activities of photosynthetic biota at this time. However, such a reduction of silica levels during the warm weather period would not necessarily lead to limiting concentrations of this element and retarded diatom development since concentrations only on the order of about one mg/l

Table 20. Summary of chemical analyses of water collected from the East Poplar River at the international boundary--nutrients and other constituents.

Stat	TN	TKjN	TON	NH_3N	NO_xN	TP	OP	COD	F	Si	D-B	D-Fe	T-Fe
November-February													
N.	9	16	8	18	26	24	17	9	15	24	16	9	14
Min	0.82	0.1	0.0	0.22	<.01	0.0	<.01	8.6	<.1	5.2	1.6	0.01	0.03
Max	1.8	2.4	1.5	1.7	0.61	0.08	0.03	34.	0.5	23.	2.5	0.12	1.3
Mean	1.24	1.18	0.52	0.95	0.11	0.03	<.01	14.8	0.3	14.6	1.9	0.06	0.51
Med	1.1	1.05	0.22	0.93	0.08	0.02	0.01	13.	0.3	15.4	1.8	0.05	0.48
March-May (low flows)													
N.	7	10	6	27	27	26	23	16	9	24	8	7	18
Min	0.27	<.1	0.30	<.01	0.0	0.01	<.01	7.7	0.2	1.5	1.1	0.01	0.13
Max	1.4	1.4	0.66	1.3	0.28	0.20	0.07	43.	0.4	16.3	2.0	0.40	1.17
Mean	0.81	0.84	0.46	0.30	0.10	0.08	0.01	19.9	0.3	7.8	1.6	0.09	0.47
Med	0.68	0.89	0.48	0.10	0.10	0.07	<.01	17.4	0.3	6.2	1.8	0.03	0.40
March-May (high flows)													
N.	2	5	2	12	13	13	11	9	4	12	3	3	12
Min	1.2	1.2	1.2	0.01	0.0	0.04	0.01	23.	0.1	3.3	0.1	0.06	0.12
Max	4.6	3.9	3.7	2.45	1.9	0.34	0.08	49.	0.2	13.3	1.0	0.24	11.
Mean	2.9	1.98	2.45	0.84	0.35	0.17	0.04	33.3	0.1	8.3	0.7	0.18	1.40
Med	2.9	1.6	2.45	0.55	0.18	0.15	0.04	35.	0.1	8.4	0.9	0.24	0.63
March-May (extreme high flows)													
N.	1	1	1	10	7	10	9	9	1	10	1	1	8
Min	--	--	--	0.23	0.03	0.03	<.01	15.	--	4.5	--	--	0.40
Max	--	--	--	2.3	0.52	0.58	0.12	57.	--	8.7	--	4.2	4.2
Mean	--	--	--	1.16	0.20	0.28	0.07	37.3	--	5.8	--	--	1.18
Med	2.2	1.7	1.5	1.05	0.18	0.28	0.08	36.	0.1	5.3	0.3	--	0.74
June-October (low flows)													
N.	9	9	9	38	42	41	31	24	14	38	14	9	34
Min	0.36	0.35	0.34	0.0	<.01	0.0	0.0	9.2	0.1	1.4	1.8	0.02	<.01
Max	1.8	1.8	1.8	1.2	0.2	0.66	0.61	32.1	0.4	9.9	3.0	0.15	0.6
Mean	1.10	1.07	1.00	0.33	0.06	0.11	<.03	16.5	0.3	3.9	2.1	0.05	0.30
Med	1.1	1.1	0.98	0.30	0.06	0.08	<.01	15.	0.3	3.0	2.0	0.03	0.31
June-October (high flows)													
N.	4	6	4	5	6	6	2	0	6	5	4	4	4
Min	0.34	0.07	0.0	0.0	0.0	0.24	0.17	--	0.1	0.9	1.3	0.04	0.40
Max	1.9	1.9	1.9	0.37	0.37	0.40	0.25	--	0.3	7.0	3.1	0.09	0.50
Mean	1.38	1.25	1.08	0.11	0.13	0.30	0.21	--	0.2	3.4	2.0	0.07	0.44
Med	1.65	1.4	1.2	0.07	0.07	0.28	0.21	--	0.2	3.7	1.7	0.08	0.44

are required by these algae (80). As a result, silica, like fluoride and iron, appears to be a non-critical water quality parameter in the East Poplar River.

The type of median-mean discrepancies that are evident in most of the nitrogen data sets in Table 20 is suggestive of slugs of nitrogenous matter such as ammonia entering the stream on occasion, as would occur from runoff events, which would tend to weight the means to higher values. But as observed for BOD, these nitrogen data are not suggestive of marked organic pollution reaching the stream. Although total nitrogen and total Kjeldahl and organic nitrogen levels appear to be relatively high, these concentrations are not excessive in view of the observation that concentrations can approach 20 mg/l and 8 mg/l of total and organic nitrogen, respectively, in weak brands of domestic sewage (89). In addition, median chemical oxygen demand (COD) values during the low flow periods were generally similar to those in natural waters. The increases in these variables and in the phosphorous species during the high flow events are probably attributable to the inputs of organic materials and nutrients at this time in conjunction with overland runoff. As indicated in Table 17, color also increased with high flows in the East Poplar, and water color is often due to soil-extractable substances such as humic and fulvic acids which can be washed into the stream via overland flow (32). During low flows however, color, like COD, declined, and the color typically exhibited by the East Poplar at this time would be barely noticeable to the naked eye (32). Thus, in terms of organic pollution, color, and turbidity, the East Poplar River at the international boundary would appear to be in an excellent condition from an aesthetic point of view, although this conclusion may have to be modified to some extent after reviewing eutrophic status of the stream.

Inorganic nitrogen concentrations are of major interest in water quality inventories in terms of their eutrophic potentials and possible toxicities. Ammonia levels were found to be relatively high in the East Poplar River, although these concentrations were much lower than those obtained from weak domestic sewage (12 mg/l) (89). Such high ammonia concentrations have been noted by all of the sampling agencies as being most distinct during the runoff periods in association with overland inputs and during the ice-covered and reducing conditions of the winter season (Table 20). In contrast to ammonia, nitrite + nitrate-N (NO_x-N) or oxidized nitrogen concentrations were relatively low during the winter and generally nondistinctive in most of the samples collected from the stream. Both the levels of ammonia and NO_x-N generally declined into the warm weather, low flow periods in accordance with the enhanced biological activities of these seasons.

The nonionic form of ammonia can be toxic to aquatic organisms when in adequate concentrations, and the ratio of unionized to ionized ammonia levels is dependent upon the pH of the water. At low pH values, this ratio is relatively low, and at the low median winter pH of the East Poplar (7.5), the proportion of nonionic ammonia would be equal to about 2.2% (24) of the total concentration with a median unionized level of about 0.02 mg/l. This value is equal to the reference criteria for ammonia (Table 15) and is above the minimal risk level for this variable; at the higher winter pH values (approaching 8.3) and at the higher ammonia levels above the median for this season, greater nonionic levels would be found (up to 0.16 mg/l) which is suggestive of toxic effects for about 50% of the cold weather period. Although ammonia

levels are lower during the summer, a similar problem exists during this season as a result of the higher pH readings with median nonionic ammonia concentrations of about 0.04 mg/l. These features plus the high pH and ammonia levels that were obtained during all of the other season-flow periods point to a sporadic ammonia toxicity problem throughout the year. In contrast to silica, therefore, ammonia may be viewed as a critical water quality parameter in the upper reaches of the East Poplar River.

In addition to its toxicity, another important aspect of ammonia resides in its potential contribution to stream eutrophy as a part of the total inorganic nitrogen (TIN) variable; i.e., TIN = NO_X-N + NH_3-N. After this calculation, the TIN value can then be referenced to the eutrophication criteria for nitrogen that has been developed previously in this report (0.35 and 0.9 mg N/l). This aspect of ammonia is particularly significant for the upper East Poplar River due to the relatively high concentrations of this variable that have been observed in this particular reach of the stream, and the time weighted TIN statistics for each of the three seasons are summarized in Table 21 for the international boundary station.

As indicated in Table 21, the high TIN concentrations obtained for the upper East Poplar during the winter season would suggest that, on the basis of nitrogen, the stream was obviously eutrophic at this time of the year. However, the winter season is possibly non-critical in this regard due to the low water temperatures and ice cover that are associated with these months, and such judgements on eutrophic status are probably best made with reference to the March-October period when the innate biological capacities of a Great Plains stream are expressed to their fullest degree. The sharp declines in TIN levels in the East Poplar through the winter, runoff, and warm weather seasons are most likely a reflection of increasing biological activities in these latter cases in response to the higher temperature values. Throughout the year, ammonia-nitrogen contributed about 79% of the nitrogen-related, eutrophic status of the upper river. The TIN data for the more critical March to October period indicate that the upper reach of the East Poplar might be possibly eutrophic due to these high ammonia levels; but such a statement has to be made with a low margin of predictive success since the mean and median TIN values are equal to or only slightly greater than the lower reference criterion for this variable (Table 21). As a result, the East Poplar at the international boundary would have TIN levels in excess of this lower criterion for only about 50% of the time during the months of March to October and in excess of the upper nitrogen value in only about 21% of the samples collected during this period. In addition, the corresponding phosphorous levels also have to be considered in eutrophic assessments since both nitrogen and phosphorus have to be non-limiting and over their respective reference levels in order to afford eutrophic conditions. Thus, the time weighted, seasonal analyses for total phosphorus are also included in Table 21.

Total phosphorous (TP) levels in the East Poplar at the international boundary were distinctively lower during the winter season than the rest of the year (Table 20), and in spite of the high TIN concentrations, the upper East Poplar can be graded as non-eutrophic during this season due to a phosphorous limitation. This was not the case for the rest of the year, however, with mean and median TP concentrations (Table 21) well over the lower reference criteria for this variable (0.05 mg P/l), and often in excess of the upper reference value established by the Environmental Protection Agency at 0.10 mg P/l (68). Thus, phosphorous concentrations in the upper river, in contrast to those

Table 21. Summary of the eutrophic status of the East Poplar River at the international boundary with reference to critical levels of nitrogen and phosphorus set at 0.9 mg N/l and 0.1 mg P/l (high probability of eutrophy) and at 0.35 mg N/l and 0.05 mg P/l (lower probability of eutrophy).

Time Weighted Total Inorganic Nitrogen Concentrations

Statistic	Winter	Runoff	Warm Weather	March-October	Annual
Minimum	0.22	<.01	<.01	<.01	<.07
Maximum	2.31	2.25	1.38	1.71	1.91
Mean	1.06	0.65	0.38	0.48	0.67
Median	1.01	0.41	0.35	0.37	0.58

Time Weighted Total Phosphorous Concentrations

Statistic	Winter	Runoff	Warm Weather	March-October	Annual
Minimum	0.0	0.02	0.01	0.01	0.01
Maximum	0.08	0.27	0.65	0.52	0.37
Mean	0.03	0.12	0.12	0.12	0.09
Median	0.02	0.11	0.09	0.10	0.07

Eutrophic Status by Season and Parameter

Season	Nitrogen	Phosphorus	Nitrogen and Phosphorus
Winter	Definitely Eutrophic	Non-Eutrophic	Non-Eutrophic
Runoff	Probably Eutrophic (medium predictive probability)	Definitely Eutrophic	Probably Eutrophic
Warm Weather	Borderline	Probably Eutrophic (high predictive probability)	Borderline
March-October	Possibly Eutrophic (low predictive probability)	Definitely Eutrophic	Possibly Eutrophic
Annual	Probably Eutrophic (medium predictive probability)	Probably Eutrophic (high predictive probability)	Probably Eutrophic

for nitrogen, were well over its critical value for much more than 50% of the March to October period. The East Poplar, therefore, appears to be more nitrogen than phosphorous limited for a large part of the year since mean and median TP concentrations demonstrated a higher ratio over its reference criteria than the case for TIN. This feature is in accord with the general observation of Gerloff and Skoog (1957) that waters are often more nitrogen than phosphorous limited. The various TP, TIN, and reference criteria ratios for the international border station can be summarized as follows (where an R denotes a reference value):

	Mean		Median	
Season	TP/low RP	TP/high RP	TP/low RP	TP/high RP
Winter	0.60	0.30	0.40	0.20
Runoff	2.40	1.20	2.20	1.10
Warm Weather	2.40	1.20	1.80	0.90
March-October	2.40	1.20	2.00	1.00
Annual	1.80	0.90	1.40	0.70
Season	TIN/low RN	TIN/high RN	TIN/low RN	TIN/high RN
Winter	3.03	1.18	2.89	1.12
Runoff	1.86	0.72	1.17	0.46
Warm Weather	1.09	0.42	1.00	0.39
June-October	1.37	0.53	1.06	0.41
Annual	1.91	0.74	1.66	0.64

As indicated by the above ratios, and regardless of the high phosphorous levels, the eutrophic status of the river at the international boundary is probably best described in terms of its inorganic nitrogen concentrations during the June to October period since nitrogen is the limiting category in this regard. As indicated in Table 21, the East Poplar River is possibly eutrophic, as has been noted previously, but due to the marginal nature of its TIN concentrations, actual field measurements of primary production levels will probably have to be conducted in order to definitely clarify the stream's eutrophic condition. However, these data do show that the upper reaches of the river will be extremely sensitive to increased nitrogen inputs to the stream, and such inputs should definitely upgrade its eutrophic status; this, in turn, could lead to a heightening of the taste and odor, filter clogging, coloration, oxygen depletion, and toxicity problems that are commonly associated with eutrophication. This of course assumes that other types of critical nutrients are not at limiting concentrations. Although phosphorus is also an important parameter in the East Poplar because of the high TP levels, future increases of phosphorus will probably be less critical than that for nitrogen in view of the naturally high and pre-developmental background concentrations of TP and in view of the stream's nitrogen limitation. As a result, the inorganic nitrogen species can be viewed as critical water quality parameters in the East Poplar River, at least with reference to its upper reach in Montana, and this feature should be considered in assessments of potential impacts derived from the Coronach development.

Metals and miscellaneous constituents.

A great deal of total recoverable and dissolved data are available for a variety of metals and trace elements in samples from the East Poplar River at the international boundary (Table 22). In addition, Table 22 also contains the

Table 22. Summary of chemical analyses of water collected from the East Poplar River at the international boundary--metals and miscellaneous constituents.

Stat	D-Al	T-Al	D-As	T-As	T-B	T-Ba	D-Be	T-Be	D-Cd	T-Cd
N.	5	16	11	19	8	3	6	14	6	22
Min	0.0	<0.05	0.0011	<.001	0.46	0.019	0.0	0.0	0.0	<.001
Max	0.04	8.1	0.027	<.025	3.70	0.1	0.005	0.01	0.001	0.02
Mean	0.02	0.813	0.0061	<.008	1.96	0.056	<.002	<.006	<.001	<.006
Med	0.02	0.135	0.002	0.005	2.0	0.05	0.0	<.005	<.001	<.010

Stat	D-Cr	T-Cr	D-Cu	T-Cu	D-Hg	T-Hg	D-Li	T-Li	D-Mn	T-Mn
N.	5	13	6	86	5	45	5	12	7	88
Min	0.0	<.010	0.0	0.0	0.0	0.0	0.010	0.020	0.0	<0.01
Max	0.010	<.05	0.007	0.05	0.0	0.015	0.110	0.150	0.200	0.42
Mean	0.002	<.013	0.002	<.011	0.0	<.0005	0.085	0.092	0.071	0.086
Med	0.0	0.010	0.001	<.01	0.0	<.00005	0.100	0.105	0.027	0.060

Stat	D-Mo	T-Mo	D-Ni	T-Ni	D-Pb	T-Pb	D-Se	T-Se	D-V	T-V
N.	5	11	5	12	6	52	13	15	6	6
Min	0.001	0.0	0.0	<.050	0.0	<.004	0.0	0.0	0.0	<.001
Max	0.002	0.003	0.004	0.100	<.004	0.100	0.0016	<.01	0.0023	<.10
Mean	0.001	0.002	0.002	<.051	<.0015	<.034	0.0004	<.002	0.0012	<.035
Med	0.001	0.002	0.002	<.050	0.0015	<.02	0.0005	<.001	0.0013	0.005

Stat	D-Zn	T-Zn	Phenols	Pesticides (ug/l)	Chl (ug/l)
N.	6	77	9	14	14
Min	0.0	<.001	<.001	<.001	<5.
Max	0.030	0.26	0.016	<.2	113.
Mean	0.010	<.015	<.007	<.026	15.5-16.9
Med	<.010	0.010	<.005	<.004	<7.

	Total Organic Carbon		
Stat	November-February	March-May	June-October
N.	7	6	8
Min	6.	8.	14.
Max	12.	20.	36.
Mean	9.4	14.8	22.1
Med	10.	14.5	21.5

statistical summaries of data collected by various Canadian agencies for four miscellaneous constituents--phenols, pesticides (combined), chlorophyll, and total organic carbon (TOC). However, except for total recoverable copper, mercury, manganese, and lead (and iron and dissolved boron), which were consistently analyzed by these Canadian entities, the numbers of analyses available for each of these parameters were relatively small when compared to that for the common ions. Thus, no attempt was made to clarify the trace element and miscellaneous constituent data on a flow or seasonal basis (except for dissolved boron, iron, and TOC).

The pesticide data in Table 22 are generally suggestive of an absence of water quality problems in this regard since their concentrations were less than the detection limits in many cases. Pesticides were detected in 21% of the samples as follows: lindane--0.001 mg/l (one out of two samples) and 2,4-D--0.04 and 0.08 mg/l (two out of four samples). Of the remaining pesticides that were analyzed, 2,4,5-T, 2,4-DB, 2,4-DP, and MPCA went undetected in four, two, one, and one sample(s) respectively. The levels obtained for lindane are also non-indicative of water quality problems since concentrations of lindane would have to be well in excess of 0.01 mg/l before fish toxicities are observed or before this insecticide begins to influence the planktonic organisms (41). This also applies to the higher concentrations of 2,4-D since the levels of this herbicide would have to be in excess of 100 mg/l to adversely effect most fish species and in excess of 0.5 mg/l to affect most types of aquatic invertebrates (41).

Phenolic compounds may pose a greater problem to water quality in the East Poplar River than the pesticides since 56% to 78% of the samples demonstrated phenol concentrations equal to or slightly greater than the 0.001 mg/l reference criteria adopted for this parameter by the Environmental Protection Agency in their National Water Quality Inventory (68). This high frequency of phenol detection is somewhat surprising in view of the lack of pollution reaching the river. However, phenols can also be derived from natural sources such as decaying vegetative matter (33), and these high phenol concentrations might be taken as the stream's natural background levels if the East Poplar is associated with marshy or swampy areas in its upper reach. In any event, the current levels of phenol in the stream would not be expected to adversely affect aquatic organisms or to taint fish flesh (Table 15); but with the relatively high concentrations that are now present, these compounds might be viewed as critical parameters in the case that these natural levels are artificially supplemented in the future by such factors as urban and industrial runoff.

All of the metals and trace elements that were analyzed for the East Poplar River were detected in some of the samples, either in their total recoverable (TR) or dissolved forms. In some cases, the constituent was detected in only a few samples and in low concentrations with the TR and dissolved, means and medians less than the detection limit for that particular parameter (e.g., beryllium and cadmium). In many instances, the constituent was detected in most of the samples but in such minute quantities that the TR and dissolved, means and medians were again very low with low maximum values (e.g., arsenic, chromium, molybdenum, selenium, and vanadium). In other cases, occasionally high TR concentrations were obtained, possibly in conjunction with high suspended sediment levels, but with relatively low TR means and medians and with consistently low dissolved concentrations. Constituents in this latter class

would include copper, lead, nickle, and zinc. The above listed, eleven parameters would not be expected to pose water quality problems to the aquatic biota with dissolved concentrations in all samples below their respective reference criteria in Table 15.

A few of the trace elements and metals demonstrated generally high TR concentrations in many of the samples but with relatively low dissolved concentrations that were below their respective reference levels in all of the analyses. These parameters, such as aluminum, boron, and manganese, might be initially misleading to a reviewer upon first consideration, especially if dissolved data are unavailable, but these three constituents were also found to be non-critical for the same reason noted above. For example, the Environmental Protection Agency in their fishery survey of the Poplar drainage (69) observed the high TR concentrations of aluminum in the East Poplar and suggested that this element may pose a toxicity problem to fish in view of its reference criterion in Table 15. However, the dissolved levels of aluminum in Table 22 indicate that this constituent does not represent a hazard to the aquatic biota of the stream, and the high TR concentrations were probably obtained in association with suspended sediment. Barium might also be added to this list since its TR concentrations were well below its reference level indicating the occurrence of low dissolved levels of this trace element. In addition, lithium is non-suggestive of water quality problems since concentrations of lithium salts on the order of 100 mg/l would be required before effects will become evident in most aquatic organisms (41).

Another class of the trace elements and metals would include those parameters with dissolved mean and/or median concentrations in excess of the reference criteria. These types of constituents would be indicative of definite water quality problems with their concentrations greater than the critical levels for a large proportion of the time. But fortunately, none of the trace elements or metals analyzed for the upper East Poplar samples would fall into this particular category. However, two of the metals might be placed into a final classification where dissolved (and TR) concentrations were in excess of the reference criteria in a few of the samples but with the mean and median levels below the critical values. These parameters are suggestive of only occasional water quality problems in a stream, but the constituents in this category are also indicative of those parameters that could pose future problems if their current concentrations happened to be supplemented by additional loadings to the stream. For the upper East Poplar, the parameters in this latter category would include iron (as discussed previously) and mercury. Although median TR concentrations of mercury were well below the average criteria of Table 15, about 16% of the samples from the upper reach did have concentrations in excess of the grab sample criterion which is indicative of a sporadic mercury problem. As a result of these occasionally high mercury values (between 0.2 and 15 micrograms per liter), the mean TR mercury concentration of the upper station (Table 22) could conceivably have been above the required average for this parameter of 0.0005 mg/l. In the main, however, none of the trace elements and metals, including iron and mercury, are suggestive of marked water quality degradations in the East Poplar River at the international boundary.

Both the TOC and chlorophyll data in Table 22 are not distinctive in relation to the numbers that have been obtained for these variables from organically polluted (TOC's approaching 100 mg C/l) and eutrophic systems (89).

The chlorophyll concentrations of the upper East Poplar are most akin to those obtained from mildly productive but non-eutrophic lakes in west-central Montana, e.g., Quake Lake near West Yellowstone (1.2 to 13.8 micrograms per liter) and Canyon Ferry Reservoir near Helena (8.0 micrograms per liter) (81, 96). The TOC concentrations of the winter season were closely equal to the 10 mg/l average value that has been obtained from unpolluted waters (87). Although TOC levels were higher during the runoff and warm weather seasons, they were not significantly greater than this average value, and the increases in TOC closely corresponded to the increases in biological activity that have been projected for the March to October period. Thus, such increases in organic matter were probably correlated with the warm weather increases in stream production, and these enhanced TOC concentrations were most likely derived from autochthonous rather than from pollutive sources.

Since most of the metals and trace elements can have adverse effects on the aquatic biota in minute concentrations, only slight increases in the concentrations of non-affecting parameters would be necessary for them to afford detrimental effects. Thus, analyses of the current concentrations of these constituents does not provide an ideal basis by which to determine which of these parameters might be most influenced by developmental impacts. But this approach does afford a first order basis for making such judgements, and continued river monitoring and a thorough impact-based review should provide further insights into these potentialities. On this first order basis, then, it would appear that iron, mercury, and possibly manganese may have the greatest potential for inflicting water quality hardships on the aquatic biota if their concentrations are supplemented through the operation of the Coronach strip mining-electrical generation facilities. As noted, however, other metals and trace elements that are now at non-critical levels in the upper East Poplar, such as copper, chromium, nickle, and zinc, could become critical if only slight concentration increases are derived from this development.

East Poplar River near Scobey

Field parameters and dissolved solids.

Although flows tended to increase downstream in the East Poplar River, the lower segment near Scobey is also a relatively small stream on the basis of discharge, as indicated in Table 23, with flows less than six cfs for a large part of the year. The annual average discharge of the river, as based on natural flow estimations for the period of record (55), increased by a factor of 1.54-times between the upper and the lower stations with a large portion of this annual downstream flow increase occurring during the March-May, runoff season (about 86%); the average downstream increases for the three seasons of interest can be summarized as follows: November-February--1.05-times, March-May--1.57-times, and June-October--1.48 times. Similar to the border site, high flows approaching 400 cfs were obtained during the March-May period, and flows on the order of 100-200 cfs were occasionally observed during the warm weather months; however, these high flow phases were of a relatively short duration as has been described previously for the upper East Poplar station. Thus, the qualities of water that are obtained during the low flow periods in the lower segment of the river also probably have the greatest effect on the stream's aquatic biota.

Table 23. Summary of chemical analyses of water collected from the East Poplar River near Scobey (lower station)--field parameters and dissolved solids.

Stat	Flow	Temp	pH	Clr	Turb	TSS	SC	DS	DO	%Sat	BOD	TC	FC
November-February													
N.	5	5	3	0	3	0	3	5	3	3	0	1	1
Min	0.38	0.0	7.9	--	2.	--	1590	1080	5.2	39	--	--	--
Max	3.9	1.0	8.3	--	10.	--	2900	2300	10.6	81	--	--	--
Mean	1.88	0.20	8.10	--	6.7	--	2060	1374	7.9	60	--	--	--
Med	1.9	0.0	8.1	--	8.	--	1690	1100	8.0	60	--	20	48
March-May (low flows)													
N.	5	4	4	0	4	1	4	5	3	3	0	3	3
Min	1.8	0.0	8.21	--	8.	--	970	634	9.1	90	--	<1	3
Max	5.9	22.0	8.5	--	30.	--	1200	938	11.8	112	--	20	86
Mean	4.04	11.4	8.35	--	17.0	--	1113	756	10.4	100	--	12	35
Med	3.8	12.8	8.35	--	15.	19.6	1140	712	10.4	97	--	16	15
March-May (high flows)													
N.													
Min													
Max						NO AVAILABLE DATA							
Mean													
Med													
March-May (extreme high flows)													
N.	2	2	0	0	0	0	2	2	0	0	0	0	0
Min	329	0.0	--	--	--	--	150E	104	--	--	--	--	--
Max	424	9.0	--	--	--	--	435E	300	--	--	--	--	--
Mean	377	4.5	--	--	--	--	293E	202	--	--	--	--	--
Med	377	4.5	--	--	--	--	293E	202	--	--	--	--	--
June-October (low flows)													
N.	8	8	5	0	5	1	8	8	5	4	1	0	2
Min	0.5E	8.0	8.4	--	7.	--	1340	1000	7.2	84	--	--	10
Max	8.1	21.0	8.88	--	65.	--	2250	1530	10.0	100	--	--	110
Mean	3.89	14.7	8.66	--	29.4	--	1726	1188	8.8	93	--	--	60
Med	3.6	15.5	8.6	--	30.	21.0	1696	1140	9.2	93	3.8	--	60
June-October (high flows)													
N.	3	3	3	0	3	1	3	3	2	2	0	0	0
Min	58	20.5	8.8	--	7.	--	1310	869	7.4	95	--	--	--
Max	195	26.1	8.9	--	10.	--	2112	1745	8.0	97	--	--	--
Mean	107	23.9	8.84	--	9.0	--	1594	1163	7.7	96	--	--	--
Med	68	25.0	8.81	--	10.	16.	1360	875	7.7	96	--	--	--

In addition to the discharge factor, the upper and lower segments of the East Poplar River were found to be similar in a variety of other features which might be expected since the two stations are separated by only a matter of 17.5 miles (28 kilometers). In the first case, temperatures were also relatively low near Scobey during the ice-covered, winter period with a distinct warming trend during the runoff and June-October periods (Table 23). No marked downstream changes in temperature became evident between the two East Poplar stations, although such data are probably too sparse at the lower station to make definitive comparisons of this kind at the present time. Like the upper station, median temperatures near Scobey were generally below the cold water reference criteria of 19.4C (44) except for the brief high flow periods during the summer, but the fact that some of the grab sample temperatures were in excess of this reference value indicates that the lower reach is also most probably either a $B\text{-}D_3$ or a marginal cold water stream. In no instances were grab sample temperatures in excess of the warm water criteria.

Similar to the case for temperature, pH and DO levels were also most suggestive of a warm water stream in the lower reach. As observed for the upper station, pH was relatively low during the reducing conditions of the winter months, and marked increases in pH were obtained through the March to October period which may be attributed to increases in biological activity at this time in response to the higher temperatures. During the warm weather period, pH values at the lower site were often in excess of the criteria for a cold water stream (pH = 8.5) (44); but in no cases were pH levels below the low extreme required for either type of fishery, and in no cases were the high summer pH's in excess of the upper value required by the warm water form (Table 7). In general, the seasonally-related, high and low extremes of pH were not as pronounced at the lower site as the case upstream, but this may be simply a reflection of the fewer number of sample collections that have been made from the lower station rather than an indication of actual in situ differences between the sampling locations.

A similar conclusion can be made for dissolved oxygen concentrations. Relatively low winter DO levels well below 100% saturation were again observed, but these lows were not as extreme for the lower reach as was the case upstream; i.e., the minimum cold weather DO near Scobey did not drop below the critical concentration for sport fish (3 mg/l), although DO did fall below the recommended levels for cold water and marginal cold water fisheries during the winter season (44, 59). As another point of similarity between the two East Poplar stations, the low coliform (below State criteria) and BOD levels throughout the year and the high DO concentrations near 100% saturation during the months of March to October indicate a lack of municipal and organic pollution entering the river between the two sampling stations. As a result, the cold weather depressions in DO near Scobey are probably attributable to natural factors, as has been described previously for the border station. With the collection of additional samples from the lower river during the winter months, extremely low DO levels for this ice-covered period might also be ultimately obtained for the downstream Scobey station, pointing to the DO-sensitive nature of the entire East Poplar in Montana during the cold weather season.

Suspended sediment-turbidity data are comparatively scarce for the East Poplar River near Scobey (Table 23), and as a result, no definite conclusions concerning the potential effect of these variables on the lower river fishery can be made at this time. The data that are available, however, indicate an

absence of marked downstream increases or changes in suspended sediment-turbidity from the border station to the stream's mouth. Similar to the upper site, therefore, the lower East Poplar is probably best graded as having a good to excellent fishery on the basis of these two parameters (Table 16). For the most part, suspended sediment and turbidity do not appear to be critical parameters in the East Poplar River.

In contrast to suspended sediment, dissolved solids concentrations apparently increased downstream in the East Poplar to some extent with a slight degradation of the fishery anticipated on this basis. Like the case for the upper station (Table 17), DS-SC levels in the lower river were also inversely related to flow with relatively low concentrations of dissolved solids obtained during the spring runoff period. Levels of DS-SC also declined somewhat during the summer high flow phases of the lower river which stands in contrast to the increases in dissolved solids that were obtained at the upper site for this same period. But the DS-SC levels at the Scobey station did not decline as much during the summer high flows as would be expected on the basis of the stream's discharge at this time (Table 23). Thus, the spring versus the summer high flows in the East Poplar probably have different origins and different hydrochemical characteristics. But since these high flow pulses are of a short duration, the low flow data from the Scobey station are probably most diagnostic of the potential fishery in the lower river, and these data indicate a good to fair-type of fishery in the lower reach on the basis of stream salinity. Using the flow distribution percentages established for the international boundary station, this fishery designation can be confirmed by calculating the yearly weighted, mean and median DS and SC concentrations for the lower station as follows: about 1110 mg/l and 980 mg/l, and about 1640 umhos and 1500 umhos respectively. These DS-SC values are between 11% and 34% greater than those calculated for the upper station, and these yearly statistics are also suggestive of a good to fair fishery in the lower reach (Table 16) rather than the "generally excellent" designation given to the stream at the international boundary location. This feature further points to the marginal character of the East Poplar fishery, as noted previously, and it also confirms the stream's general susceptibility to slight increases in salinity levels.

Reviewing the "field" parameter data for the East Poplar River in Montana, Tables 17 and 23, the dissolved and suspended solids concentrations of the stream are suggestive of a generally good, prairie-type of fishery. Since the East Poplar is a relatively small stream for large proportion of the year, this description, of course, assumes that its various physical features, such as depth, current, volume, and discharge, are also amenable to the survival of appropriate fish species. However, the salinity levels of the stream are marginal in relation to this "good" classification, and the relatively small downstream increases of this variable point to a slight degradation of the fishery in the lower reach. This indicates that the inputs of groundwater and surface water between the two East Fork sites, affording the slightly greater downstream flows, probably have an inferior quality of water in comparison to that of the main river per se. The other "field" parameters, temperature, pH, DO, the coliforms and BOD, indicate that the East Poplar probably possesses an unpolluted, $B\text{-}D_3$ type of water that is primarily suited to a warm water fishery; but the $B\text{-}D_2$ or marginal cold water designation assigned by the State of Montana (44) also appears to be applicable to the East Poplar on the basis of these field data. Of these variables, dissolved oxygen, along with salinity, is probably most critical to the stream in relation to the low values that were obtained

during the ice-covered, winter season, and temperature is additionally critical in relation to the cold water, fishery classification.

Common constituents.

Common constituent concentrations were generally similar between the upper and lower segments of the East Poplar River and inversely related to flow, although some of the constituents demonstrated higher concentrations downstream, e.g., sodium and sulfate, during some seasons in keeping with the greater salinity levels of the lower reach. In contrast to the non-saline waters of the upper reach, the station near Scobey might be classified as slightly saline during the June to February period while being largely non-saline during the months of March to May (58). Except for the high flows during the spring, the waters of the lower reach were very hard (10, 19) with high total hardness concentrations even though calcium and magnesium did not represent the major cations of the stream (Table 24). As observed for the upper reach, the waters in the river near Scobey were sodium bicarbonate in nature with high total alkalinities throughout the year. Calcium, magnesium, and sulfate were representative of secondary ionic constituents in the samples, and carbonate concentrations were occasionally quite high in conjunction with the higher pH values. In contrast, carbon dioxide concentrations were relatively high during the low pH, winter season. Potassium and chloride continued to be insignificant constituents of the East Poplar waters, although the concentrations of the latter two variables tended to increase slightly from the border station to Scobey. Apart from adding to the salinity factor which has been discussed previously, none of the common ions appeared to be at adequate levels to individually affect the aquatic biota of the lower river.

Although the concentrations of specific ions were generally similar between the two sampling stations, some distinct, downstream changes in ionic composition did become evident in the East Poplar River, and such changes in ionic composition also became evident on a seasonal basis. These features can be illustrated through the various ionic concentration ratios that are summarized in Table 25; such ratios were calculated from the median concentrations of ions for the various seasonal-flow periods and for the several sampling sites. Ionic concentration ratios for the other sampling locations in the Poplar River drainage are also listed in this table, and these data will be discussed elsewhere in this report.

The sodium bicarbonate nature of the East Poplar River is also illustrated in Table 25 by the relatively high HCO_3/SO_4 and $Na/(Ca + Mg)$ ratios that were obtained during all of the seasons and flow regimes at both of the sampling sites. However, the river becomes more sodium sulfate in character downstream in view of the lower HCO_3/SO_4 and the higher $Na/(Ca + Mg)$ ratios in water samples from the Scobey station. In the upper reach, calcium is a more prevalent ion than magnesium on a weight basis, except for the warm weather season, with Ca/Mg ratios greater than one. However, magnesium becomes more predominant than calcium in the lower reach with median ratios less than one throughout the year. This prevalence of magnesium in the East Poplar waters would be more distinct on an equivalents basis since magnesium demonstrates a lower atomic weight per valence than the case for calcium. These various features indicate that groundwater and surface water inputs to the river below the international boundary are probably quite sodium sulfate in character with a high proportion of magnesium ions. This, in turn, is reflected by the generally

Table 24. Summary of chemical analyses of water collected from the East Poplar River near Scobey (lower station)--common constituents.

Stat	CO_2	HCO_3	CO_3	TA	PA	Cl	SO_4	Ca	Mg	TH	Na	SAR	%Na	K
November-February														
N.	3	5	4	5	0	5	5	5	5	5	5	5	5	5
Min	5.3	661	0.0	542	--	8.2	330	43.	48.	330	260	5.9	59.	9.7
Max	20.	1560	33.	1280	--	22.	690	85.	130.	750	550	8.8	63.	24.
Mean	13.1	896	8.3	746	--	11.8	424	58.2	72.4	444	332	6.8	61.0	14.7
Med	14.	757	0.0	621	--	10.	360	57.	63.	370	270	6.5	61.	13.
March-May (low flows)														
N.	3	5	4	5	0	5	5	5	5	5	5	5	4	4
Min	2.1	400	0.0	340	--	5.2	183	36.	35.	240	140	4.0	54.	5.9
Max	4.0	503	7.	420	--	6.5	250	48.	42.	290	190	5.1	61.	13.
Mean	3.4	477	3.0	395	--	5.9	209	39.6	39.2	261	163	4.4	57.0	8.4
Med	3.2	494	2.5	405	--	5.8	200	38.	39.	260	160	4.4	56.5	7.4
March-May (high flows)														
N.														
Min														
Max						NO AVAILABLE DATA								
Mean														
Med														
March-May (extreme high flows)														
N.	0	2	0	2	0	2	2	2	2	2	2	2	2	2
Min	--	86	--	71	--	0.6	18	13.	6.3	58	11	0.6	27.	6.2
Max	--	185	--	152	--	2.8	93	23.	14.	120	60	2.4	51.	9.0
Mean	--	136	--	112	--	1.7	56	18.0	10.2	89	35.5	1.5	39.0	7.6
Med	--	136	--	112	--	1.7	56	18.	10.2	89	35.5	1.5	39.	7.6
June-October (low flows)														
N.	4	7	4	8	0	8	8	8	8	7	8	7	7	7
Min	1.8	600	9	520	--	7.7	310	20.	48.	280	270	7.0	65.	13.
Max	4.3	933	49	675	--	16.	480	40.	70.	360	430	9.8	70.	33.
Mean	2.9	714	23	602	--	10.8	380	32.5	57.0	310	313	7.8	66.9	20.7
Med	2.8	698	17	597	--	10.3	360	34.5	56.	300	298	7.1	66.	20.
June-October (high flows)														
N.	2	3	3	3	0	3	3	3	3	3	3	3	2	3
Min	1.1	427	44	435	--	3.0	260	29.5	37.	220	230	6.3	64.	20.
Max	1.4	744	51	690	--	8.4	450	36.	57.	308	308	9.5	67.	30.
Mean	1.3	549	48	530	--	6.5	330	31.2	44.3	259	281	7.5	65.5	23.3
Med	1.3	476	48	464	--	8.2	280	28.	39.	250	230	6.7	65.5	20.

Table 25. Median ionic concentration ratios calculated on a flow-seasonal basis for various sampling locations in the Poplar River drainage (IB-international boundary).

Season-Flow	HCO_3/SO_4	Na/(Ca + Mg)	Ca/Mg	HCO_3/SO_4	Na/(Ca + Mg)	Ca/Mg
	East Poplar River-IB			East Poplar River-Scobey (mouth)		
November-February, low	3.00	1.58	1.55	2.10	2.25	0.90
March-May, low	3.21	1.21	1.29	2.47	2.08	0.97
March-May, high	3.35	1.12	1.41	--	--	--
June-October, low	2.73	1.85	0.87	1.94	3.29	0.62
June-October, high	1.82	4.41	0.47	1.70	3.43	0.72
	Middle Fork Poplar-IB			Middle Fork Poplar-Scobey (mouth)		
November-February, low	3.06	1.46	1.16	2.62	2.94	1.08
March-May, low	2.70	1.70	1.09	3.13	2.18	1.00
March-May, high	--	--	--	4.36	1.66	1.63
June-October, low	2.53	2.94	0.95	2.19	3.77	0.72
June-October, high	--	--	--	4.05	2.07	1.15
	West Fork Poplar-IB			West Fork Poplar-Four Buttes, Bredette (mouth)		
November-February, low	3.16	4.10	0.93	4.36	4.10	1.50
March-May, low	4.76	3.11	1.37	5.40	4.97	1.33
March-May, high	--	--	--	3.09	2.68	2.46
June-October, low	2.88	5.91	0.63	4.09	8.22	0.97
June-October, high	--	--	--	4.21	3.51	1.40
	Poplar River mainstem-Bredette (lower reach)			Poplar River mainstem-Poplar (mouth)		
November-February, low	2.16	3.15	0.94	2.66	3.59	1.06
March-May, low	2.56	2.50	0.87	3.17	3.85	1.16
March-May, high	2.44	2.31	1.10	2.59	2.85	1.16
June-October, low	1.93	3.57	0.58	2.06	4.93	0.64
June-October, high	2.09	4.60	0.65	2.40	3.58	1.01

higher SAR and percent sodium (%Na) values that were obtained in water samples from the Scobey site over those that were obtained from the border collections (Tables 19 and 24). In addition, seasonal changes in ionic composition are also indicated by the SAR and %Na variables with generally higher values obtained during the summer than during the spring; intermediate SAR and %Na levels were obtained during the winter season, and comparatively low SAR and %Na values were observed in conjunction with the spring runoff period.

On a seasonal basis, the East Poplar is more calcium-magnesium bicarbonate in character in the spring than during the summer and winter months with an increase in HCO_3/SO_4 and a decrease in Na/(Ca + Mg) ratios going into the March-May period. The river is most sodium sulfate in nature during the summer with the lowest HCO_3/SO_4 and the highest Na/(Ca + Mg) ratios at this time. The more sodic tendencies of the stream into the summer season, as illustrated by the following seasonal progression--summer > winter > spring, is also reflected by the higher SAR and %Na values of the warm weather samples, as described previously. In addition, magnesium becomes more predominant during the summer season in showing significantly lower Ca/Mg ratios than the November to May period. Waters in the river during the spring, high flow period are much more calcium bicarbonate in character than the stream's low flow waters with the HCO_3/SO_4 and Ca/Mg ratios and the Na/(Ca + Mg) ratio at this time at their highest and lowest values respectively. In contrast, the warm weather high flows have a composition that is generally quite "opposite" to that of the spring runoff waters in demonstrating the lowest and the highest HCO_3/SO_4-Ca/Mg and Na/(Ca + Mg) ratios respectively. This points to the fact that the spring and summer runoff waters have different hydrologic origins as noted earlier. However, a portion of the seasonal changes in chemical composition of the river water may also have been due to biotic factors in the stream as well as to differences in input qualities.

Since calcium carbonate is relatively insoluble at high pH, a part of the decline in HCO_3/SO_4 ratios during the summer season may have been due to a biogenetic precipitation of bicarbonate as $CaCO_3$ under the high biological-photosynthetic activities of the warm weather period with its associated high pH conditions (and the high carbonate levels). The photosynthetic utilization of bicarbonate along with its biogenetic precipitation would remove this ion from the aqueous phase and cause a decline in the HCO_3/SO_4 ratio. Such a precipitation, in turn, would also account for the increase in Na/(Ca + Mg) ratios during the summer with calcium as well as bicarbonate leaving the water system. This precipitation would also account for the marked, summer decline in Ca/Mg ratios for the same reason since the $MgCO_3$ salt is much more soluble at high pH than the case for $CaCO_3$. All of these features, then, also correspond to the distinct decline in silica during the summer at both stations (Tables 20 and 26) which has been attributed to a diatom utilization during this biological active season. As a result, since biotic activity is at a minimum during the winter, the ionic composition of the river during this season is probably reflective of qualities in the stream's baseline flow component. The alteration of composition in the spring from that in the winter is probably related to runoff inputs to the stream from snowmelt and overland travel in the region. Changes in chemical composition during the summer low flows from that in the winter are probably a reflection of biological activity, at least to some extent, while those obtained during the summer high flow phases are probably related to a combination of features--biotic effects coupled with that of some unknown factor or input having a distinctly sodium sulfate characteristic.

Nutrients and other constituents.

Mean and median concentrations of fluoride, silica, dissolved boron, and iron in samples from the East Poplar near Scobey (Table 26) were generally similar to those obtained from the river at the international boundary (Table 20). If anything, the concentrations of these variables showed a slight downstream decline, and this decline was most obvious in the case of silica. Silica levels at the lower station were typically well below the median value of this parameter for the nation's surface waters (83) during all of the seasons (in 95% of the samples), and the downstream decrease in this constituent might have been due to a silica utilization by periphyton in the upstream reaches in the face of a low silica loading to the river between the two sampling locations. In contrast to the upper station, dissolved iron levels at the lower station did not exceed the reference criteria for this variable (Table 15) in any of the samples analyzed for this constituent. Thus, these four variables would not be expected to pose water quality problems in the lower segments of the stream.

With respect to the critical nutrients, the upper and the lower segments of the East Poplar River were generally similar in their phosphorous aspects but distinctively different in terms of their nitrogen characteristics. As observed for the upper station on the river, phosphorous concentrations in the lower reach were primarily in the TP form with relatively low orthophosphate (OP) levels in the water samples during all seasons except for the high flow summer season (Table 26). No consistent and distinct downstream changes in phosphorous levels became evident in the stream, either in the TP or in the OP forms. Concentrations of phorphorus were again relatively low during the winter season, and the lower reach of the river, like the upper station, was also P-limited during these months. But TP concentrations generally increased through the March-October period at both sites, and relatively high phosphorous concentrations were obtained during the warm weather, runoff period. Mean and median levels of TP at these times were in excess of the reference criteria for this particular nutrient, and the lower portion of the river, thereby, was not limited by phosphorus for a major and critical portion of the year.

Mean and median concentrations of total nitrogen and total Kjeldahl and organic nitrogen were generally similar between the two river segments, and these concentrations were indicative of an absence of organic-municipal pollution reaching the stream. Regardless of the general similarities between reaches in relation to the combined nitrogen species, however, and in contrast to the case for phosphorus, TIN levels provide a major water quality distinction between the upper and lower segments of the East Poplar River. Inorganic nitrogen concentrations, both ammonia and nitrite-nitrate, were markedly lower at the downstream station than was the case at the international boundary, and this is evident either on a mean, median, or maximum basis (Tables 20 and 26). With the lower total ammonia levels downstream, the concentrations of the toxic, nonionized form would not be expected to exceed its critical reference value (Table 15) on very many occasions at the pH levels of the lower river. In addition, the development of such reduced ammonia concentrations downstream, coupled with the comparatively low NO_x-N levels, would indicate that the lower East Poplar River was definitely non-eutrophic during the period of sampling. In view of the high TP levels, the river appeared to be significantly N-limited during the important March-October, warm weather season. TIN concentrations were comparatively high during the winter season of low biological activity,

Table 26. Summary of chemical analyses of water collected from the East Poplar River near Scobey (lower station)--nutrients and other constituents.

Stat	TN	TK_jN	TON	NH_3N	NO_xN	TP	OP	COD	F	Si	D-B	D-Fe	T-Fe
November-February													
N.	3	3	3	3	5	3	5	0	5	5	5	5	0
Min	0.68	0.64	0.30	0.0	0.0	0.03	0.0	--	0.3	3.9	1.1	0.01	--
Max	2.2	1.3	0.67	1.3	0.60	0.06	0.06	--	0.5	29.	3.7	0.10	--
Mean	1.25	0.97	0.45	0.52	0.17	0.04	0.02	--	0.4	11.2	2.0	0.04	--
Med	0.88	0.67	0.38	0.26	0.01	0.03	0.0	--	0.3	9.1	1.8	0.04	--
March-May (low flows)													
N.	3	3	3	4	5	4	5	0	5	4	4	4	1
Min	0.68	0.53	0.53	0.0	0.0	0.03	0.0	--	0.2	2.9	0.8	0.01	--
Max	1.1	1.1	1.1	<.01	0.30	1.13	0.02	--	0.8	4.8	1.2	0.04	--
Mean	0.83	0.77	0.77	<.01	0.10	0.06	0.01	--	0.4	3.9	1.0	0.03	--
Med	0.72	0.67	0.67	0.0	0.02	0.05	0.01	--	0.3	4.0	1.1	0.03	0.84
March-May (high flows)													
N.													
Min													
Max						NO AVAILABLE DATA							
Mean													
Med													
March-May (extreme high flows)													
N.	0	0	0	0	2	0	2	0	2	2	2	2	0
Min	--	--	--	--	0.33	--	0.04	--	0.1	3.5	0.1	0.12	--
Max	--	--	--	--	0.65	--	0.05	--	0.3	4.5	0.5	0.13	--
Mean	--	--	--	--	0.49	--	0.045	--	0.2	4.0	0.3	0.125	--
Med	--	--	--	--	0.49	--	0.045	--	0.2	4.0	0.3	0.125	--
June-October (low flows)													
N.	4	5	4	5	8	5	7	0	7	7	7	7	1
Min	1.3	0.41	1.3	0.0	0.0	0.05	0.0	--	0.3	0.7	1.5	0.02	--
Max	1.9	1.9	1.9	0.07	0.05	0.24	0.60	--	0.3	4.0	3.2	0.07	--
Mean	1.50	1.28	1.48	0.02	0.01	0.16	0.09	--	0.3	2.1	2.1	0.04	--
Med	1.4	1.3	1.35	<.01	0.005	0.18	0.01	--	0.3	2.3	2.0	0.04	0.45
June-October (high flows)													
N.	2	3	2	3	3	3	3	0	3	2	2	2	1
Min	1.3	0.39	1.3	0.0	0.0	0.20	0.07	--	0.1	0.4	1.6	0.04	--
Max	1.4	1.4	1.4	0.06	0.02	0.23	0.17	--	0.3	2.6	1.7	0.06	--
Mean	1.35	1.03	1.35	0.02	0.01	0.21	0.13	--	0.2	1.5	1.65	0.05	--
Med	1.35	1.3	1.35	0.0	0.0	0.21	0.16	--	0.2	1.5	1.65	0.05	0.43

but the low tenperatures and the low phosphorous levels at this time would probably preclude eutrophication. Only about 9% of the samples collected from the lower river throughout the year would be expected to have both TP and TIN concentrations in excess of the lower reference criteria for these critical nutrients. Thus, neither eutrophy nor ammonia toxicity would appear to be major water quality problems in the lower segments of the East Poplar River.

Metals and miscellaneous constituents.

All of the trace elements and metals analyzed for samples from the upper station of the East Poplar River, except for the phenols, pesticides, and chlorophylls, were also analyzed at the Scobey site in their total recoverable and dissolved forms, adding TR cobalt and strontium (Table 27). However, the numbers of analyses for most of the parameters were much smaller at the downstream location, and as a result, water quality judgements will be less secure for the Scobey reach. As observed for the upstream station, most of these constituents were detected at the Scobey site in at least one of the samples in either their dissolved or TR forms or both, excluding cobalt and mercury, but the individual and mean-median concentrations of these variables were generally quite low. In most instances, metal and trace element concentrations were either generally similar between the two East Poplar stations, or they demonstrated a downstream decline. Thus, none of these constituents, including cobalt, would be expected to pose water quality problems to the lower segment of the river since none of their dissolved concentrations were in excess of the corresponding reference criteria in Tables 7 and 15. In addition, iron, manganese, and mercury concentrations are less suggestive of problems in this lower reach than was the case upstream.

MAIN INVENTORY STREAM--EAST POPLAR RIVER IN SASKATCHEWAN

Geographic and Sampling Features

The East Poplar River in Canada is comprised of two major branches that drain the eastern portions of the upper Poplar River Basin in Saskatchewan. The eastern branch, or the East Poplar River, drains the extreme eastern segment of the region, and a western branch, or Girard Creek, drains the east-central part of the upper basin with the creek's headwaters found in the vicinity of Fife Lake (Figure 1). Fife Lake is a relatively large but shallow body of water whose levels can fluctuate markedly from year to year; it represents the largest lentic system in the Poplar Basin. However, Fife Lake rarely spills into Girard Creek, except during the occurrences of extremely wet years, and as a result, this lake and a large part of the surrounding area can be generally excluded from the East Poplar's effective drainage area (55).

As indicated in Table 5, various Canadian entities have sampled both of these streams to varying degrees so that fair amounts of water quality data are now available for the two upstream branches of the East Poplar River. The Coronach town reservoir is located on Girard Creek at a short distance above the point where this stream joins the East Poplar, about three miles (five kilometers) above the United States-Canadian border, and some data are available for both the inlet to and the outlet from this body of water. The dam for the electrical generation development is located below the confluence of the two streams. The sampling site on the East Poplar per se, or the eastern branch, is also located near Coronach and above the confluence of Girard Creek. No

Table 27. Summary of chemical analyses of water collected from the East Poplar River near Scobey (lower station)--metals and miscellaneous constituents.

Stat	TOC	D-Al	T-Al	D-As	T-As	T-B	T-Ba	D-Be	T-Be
N.	1	3	2	3	2	2	1	3	1
Min	--	0.0	0.15	0.001	<.001	0.83	--	0.0	--
Max	--	0.03	0.2	0.006	0.001	1.6	--	0.005	--
Mean	--	0.01	0.175	0.004	<.001	1.22	--	0.002	--
Med	17.	0.0	0.175	0.004	<.001	1.22	0.2	0.0	<.01

Stat	D-Cd	T-Cd	T-Co	D-Cr	T-Cr	D-Cu	T-Cu	D-Hg	T-Hg
N.	3	3	1	3	3	3	3	3	3
Min	0.0	<.001	--	0.0	<.05	0.0	<.01	0.0	<.0002
Max	0.001	0.001	--	0.01	<.05	0.002	<.01	0.0	<.0002
Mean	0.001	<.001	--	0.003	<.05	0.001	<.01	0.0	<.0002
Med	0.001	<.001	<.01	0.0	<.05	0.001	<.01	0.0	<.0002

Stat	D-Li	T-Li	D-Mn	T-Mn	D-Mo	T-Mo	D-Ni	T-Ni
N.	3	1	11	3	3	1	3	1
Min	0.07	--	0.0	0.04	0.0	--	0.002	--
Max	0.11	--	0.10	0.13	0.002	--	0.004	--
Mean	0.10	--	0.022	0.08	0.001	--	0.003	--
Med	0.11	0.08	0.01	0.08	0.001	<.10	0.004	<.01

Stat	D-Pb	T-Pb	D-Se	T-Se	T-Sr	D-V	T-V	D-Zn	T-Zn
N.	3	3	3	2	1	3	2	3	3
Min	0.0	<.05	0.0	<.001	--	0.0003	<.10	0.0	<.01
Max	0.003	<.05	0.001	<.001	--	0.0035	<.11	0.02	0.03
Mean	0.002	<.05	0.0003	<.001	--	0.0014	<.11	0.007	<.02
Med	0.002	<.05	0.0	<.001	0.58	0.0004	<.11	0.0	<.01

flow data were collected from these streams by Canadian agencies in association with their water quality sampling programs, but it might be assumed on the basis of previous discussions that the Coronach reach of the East Poplar and Girard Creek are representative of fairly small streams. Due to this lack of flow data, water quality information for the Canadian segment of the East Poplar was flow classified in relation to the corresponding discharges that were obtained from the East Poplar River at the international boundary. Water quality data for Girard Creek were classified only on a seasonal and yearly basis.

East Poplar River near Coronach

Field parameters and dissolved solids.

As indicated in Table 28, the Canadian segment of the East Poplar, like the Montana reach, is probably unpolluted in view of the relatively low BOD_5 and coliform concentrations that were obtained from the Coronach station. Total and fecal coliform levels were below Montana's standards for these parameters (44) in all of the samples. BOD_5 concentrations at the international boundary (IB) location were possibly somewhat lower than those at the Coronach site, as were the coliform levels, and this feature coupled with the fact that DO concentrations were possibly slightly lower upstream with lower %Sat values indicates that the Coronach reach may have contained higher levels of organic matter than the Montana segment. But as noted previously, such higher levels of organic materials would not be at adequate concentrations to be suggestive of organic pollution reaching the stream. For example, median BOD_5 levels in organically polluted streams often approach 15 mg/l (86), and the BOD_5 parameter is generally not considered to be critical until concentrations on the order of at least 5 mg/l are consistently achieved in sluggish streams (41). In view of this information and the data in Tables 17, 23, and 28, the BOD_5 and coliform levels in the East Poplar were most likely derived from natural sources and not representative of water quality problems in the stream. Assuming that the upper reaches of the river near Coronach are associated with swampy and marshy regions, as has been suggested previously, somewhat higher organic levels would be expected in such a stream reach as a matter of course. The distinct DO depression that was obtained during the winter season in the Coronach reach was also most probably a reflection of natural factors as has been described for the IB station. Such low winter DO levels might be viewed as a critical water quality feature of the Canadian segment of the river; however this feature is probably not related to human intervention, but rather, to the ice cover of the winter season.

For the most part, turbidity-suspended sediment and color levels in the Coronach reach of the East Poplar were essentially similar to those observed for the IB site during all seasons, and in both locations, these variables increased in correspondence with the increased flows of the runoff periods. The yearly weighted mean and median values for turbidity in JTU and color in standard units, using the flow distribution percentages developed earlier, can be estimated for the East Poplar near Coronach and at the IB as follows:

Sampling Station	Mean Turbidity	Median Turbidity	Mean Color	Median Color
near Coronach	8.3	7.4	10.6 to 16.2	10.1
at the IB	10.2	7.2	11.3 to 17.7	12.1

The similarity of these data suggest that the sediment and color loading to

Table 28. Summary of chemical analyses of water collected from the East Poplar River near Coronach, Canada (above Girard Creek)--field parameters and dissolved solids. (Discharge data are not available for this site; flow classifications are based on East Poplar discharges at the international boundary.)

Stat	Flow	Temp	pH	Clr	Turb	TSS	SC	DS	DO	%Sat	BOD	TC	FC
November-February													
N.	0	2	11	10	10	1	11	11	2	1	1	1	1
Min	--	0.2	7.3	<5	1.3	--	1050	691	3.2	--	--	--	--
Max	--	2.5	8.20	30	11.	--	1400	1210	5.7	--	--	--	--
Mean	--	1.9	7.66	<8	6.0	--	1196	872	4.5	--	--	--	--
Med	--	1.9	7.60	5	6.7	21	1150	861	4.5	26	2.6	<23	<23
March-May (low flows)													
N.	0	1	18	16	16	2	18	18	1	1	2	2	2
Min	--	--	7.51	<5	1.2	10.	383	239	--	--	3.0	90	<23
Max	--	--	8.50	65	27.	21.	1325	988	--	--	3.8	230	40
Mean	--	--	8.03	<17	8.1	15.5	897	685	--	--	3.4	160	<32
Med	--	16	8.03	10	5.9	15.5	915	732E	9.5	105	3.4	160	<32
March-May (high flows)													
N.	0	2	13	12	12	1	13	13	2	1	1	1	1
Min	--	9.0	6.4	15	5.4	--	242	171	7.5	--	--	--	--
Max	--	14.5	8.1	70	51.	--	851	661	9.9	--	--	--	--
Mean	--	11.8	7.68	50	17.8	--	508	354	8.7	--	--	--	--
Med	--	11.8	7.8	53	12.3	38	500	338	8.7	81	5.0	70	40
March-May (extreme high flows)													
N.	0	1	8	8	8	0	8	8	1	0	0	0	0
Min	--	--	6.35	30	17.	--	108	90	--	--	--	--	--
Max	--	--	8.05	100	150.	--	280	236	--	--	--	--	--
Mean	--	--	7.56	56	85.4	--	171	140	--	--	--	--	--
Med	--	2.0	7.63	45	73.5	--	144	113	9.2	--	--	--	--
June-October (low flows)													
N.	0	4	28	25	25	2	28	28	3	1	3	3	3
Min	--	5.0	7.6	<5	1.4	9	620	441	9.0	--	1.6	90	<23
Max	--	20.0	8.33	70	7.1	9	1525	1507	9.1	--	4.6	750	390
Mean	--	11.6	8.06	14	3.7	9	1116	807	9.1	--	2.9	330	<151
Med	--	10.8	8.05	5	3.6	9	1140	794	9.1	82	2.6	150	40
June-October (high flows)													
N.													
Min													
Max						NO AVAILABLE DATA							
Mean													
Med													

the river occurs to a large extent in the stream's headwaters area with relatively minor inputs developing below the Coronach station and producing only slight increases in these variables downstream. As indicated in Table 28, the river was essentially uncolored (32) and non-turbid during the low flow phases of the year, but the stream became definitely colored and turbid during the high flow periods as a result of runoff and overland flow reaching its course at this time. But since these runoff events have a relatively short duration in the East Poplar River (about 9% of the year), its Canadian and Montana segments appear to be in an excellent condition from the standpoint of the stream's aesthetics. In addition, the low flow and yearly weighted mean and median turbidity values indicate that the Coronach reach of the East Poplar, like the IB segment, should provide a good to excellent class of fishery on the basis of suspended sediment (Table 16). The high flow values of turbidity and the maximum levels of this variable in each of the seasons do not appear to be at adequate concentrations or of long enough duration to significantly detract from this classification.

A great deal of temperature data are not now available for the Coronach station of the East Poplar (Table 28), but the information that has been collected suggests that the waters at this extreme upper site might be slightly cooler overall than those at the downstream locations. This feature would make the Coronach segment more in accord with Montana's B-D_2 designation for the Poplar Basin. Although mean and median pH values were generally similar between the Coronach and IB water samples, the high extremes noted for the downstream sites were generally absent from the Canadian reach. As a result, pH values at the Coronach site were consistently within the required range for a cold water fishery (6.5 to 8.5), and this also makes the Canadian segment more akin to Montana's B-D_2 designation than the case downstream. However, the low winter DO values that were obtained in samples from the Coronach station would also tend to negate this classification for the extreme upper segment during the cold weather months. Game fish, if present, would probably be threatened by the occurrence of such low winter dissolved oxygen concentrations and ultimately forced to migrate out of the upper East Poplar River during this season.

The waters in the Canadian segment of the East Poplar River, with the exception of a very few samples collected during the summer and winter seasons, were largely non-saline throughout the year (58). Similar to the Montana sites, DS and SC levels at the Coronach station appeared to be inversely related to flow (Table 28), but the minimum, maximum, mean, and median values for these two variables were generally lower in each of the seasons and flow ranges at this location than the values that were obtained downstream (in 95% of the comparisons). This is in keeping with the downstream trend of DS-SC increases between the IB and the stream's mouth. The yearly or time weighted, mean and median DS-SC levels for the Coronach site were estimated at 775 mg/l and 1060 umhos (the same values for both statistics), and these levels are between 7.2% and 15.5% lower than the weighted mean and median values of DS-SC at the IB. In turn, these values are between 21.1% and 30.2% lower than those obtained from the Scobey station. On this basis, therefore, qualities of water appear to be somewhat better in the progressively upstream segments of the river, and the extreme upstream waters should afford a generally excellent and less marginal class of fishery in terms of salinity than the downstream reaches in Montana; this designation assumes that the other water quality factors of the stream and its various physical features are also non-limiting to appropriate fish species.

Common constituents.

Similar to the Montana segment of the East Poplar River, waters at the Coronach site on the stream were also largely sodium bicarbonate in character throughout most of the year (Table 29). During the high flows of spring, however, the river at this location had a calcium bicarbonate-type of water which corresponds to the downstream tendency of the river to become more calcium bicarbonate in composition and less saline during this high flow period. On the basis of weight, bicarbonate was by far the dominant ionic constituent of samples collected from the stream in all seasons and at all locations, comprising between 47% and 57% of the East Poplar's total salinity during the winter and summer months. As a result, the river demonstrated relatively high total alkalinities that were on the order of 4.5-times greater during the low flow periods than Montana's surface water average for this parameter (12). Sodium was the dominant cation in the Coronach samples during periods of reduced flow, equalling about 12.9% to 20.2% of the stream's total salinity, with calcium and magnesium representative of secondary cations and with sulfate representative of a secondary anionic component. Concentrations of chloride and potassium were again largely negligible upstream and generally similar to those obtained for the Montana stations. But in contrast to the IB site, levels of carbonate and phenolphthalein alkalinity were more commonly found at zero in the Coronach samples in response to the lower pH values that were typically obtained at this site for most of the year.

Although total alkalinity and total hardness concentrations were generally similar between the three sampling sites on the river, e.g., very hard waters in most cases, calcium and bicarbonate accounted for higher proportions of the stream's salinity in the Canadian segment than was the case for the Montana reach. That is, higher HCO_3/SO_4 and Ca/Mg ratios and a lower Na/(Ca + Mg) ratio were generally obtained from the Coronach samples than from the downstream collections in all seasons. For example, these ionic concentration ratios for the summer and winter periods at Coronach equalled 3.38 and 3.13, 1.44 and 1.35, and 1.23 and 1.17, respectively, which stand in contrast to the values for these ratios listed in Table 25 for the lower East Poplar stations. In addition, values for %Na were typically lower in samples from the more upstream sampling sites. As a result, these differences in ionic composition at the extreme upstream station are in accord with the observation that the river tends to become more sodium sulfate in character, as well as more saline, in a downstream direction from the IB to Scobey, Montana.

Nutrients and other constituents.

The mean-median discrepancies that are evident in Table 30 for ammonia, in contrast to the much closer similarities between the mean-median levels of total phosphorus, for example, plus the wide differences between the minimum and maximum values of ammonia in each season are suggestive of fairly large concentrations of this constituent (often in excess of 2.0 mg NH_3-N/l) sporadically entering the East Poplar River at points throughout the year, as would occur from runoff events. But the relatively high median concentrations of ammonia also indicate that these "slugs" occur "on top" of a fairly high baseline level of this variable in the stream as might be developed from steady groundwater inputs having significant ammonia concentrations. Although total Kjeldahl and ammonia nitrogen levels were relatively high in the Coronach samples, particularly under the reducing conditions of winter and/or during the

Table 29. Summary of chemical analyses of water collected from the East Poplar River near Coronach, Canada (above Girard Creek)--common constituents. (Discharge data are not available for this site; flow classifications are based on East Poplar discharges at the international boundary.)

Stat	CO_2	HCO_3	CO_3	TA	PA	Cl	SO_4	Ca	Mg	TH	Na	SAR	%Na	K
November-February														
N.	1	2	2	11	11	11	11	11	11	11	11	0	1	11
Min	--	594	0.0	460	0.0	2.6	150	60.	39.4	370	114	--	--	8.
Max	--	676	0.0	592	0.0	10.	259	98.	68.	445	191	--	--	23.
Mean	--	635	0.0	542	0.0	4.3	192	76.8	51.5	400	156	--	--	12.6
Med	37.6	635	0.0	548	0.0	4.0	188	75.	52.	400	156	--	40.2	13.
March-May (low flows)														
N.	0	2	2	18	16	18	18	18	18	18	18	0	0	18
Min	--	505	0.0	152	0.0	<.3	39	24	15	122	28	--	--	8.
Max	--	561	0.0	494	23.	8.	240	93	64	460	140	--	--	21.8
Mean	--	533	0.0	400	1.4	1.7	129	61.8	44.6	338	94	--	--	12.9
Med	--	533	0.0	425	0.0	1.0	139	58.5	46.5	315	92	--	--	11.6
March-May (high flows)														
N.	1	2	2	13	13	13	13	13	13	13	13	0	1	13
Min	--	203	0.0	100	0.0	0.9	25	19.	11.	92	14	--	--	8.
Max	--	534	0.0	438	0.0	8.	149	73.4	45.8	372	108	--	--	25.
Mean	--	369	0.0	225	0.0	2.8	65	39.6	22.2	190	45	--	--	12.6
Med	13.5	369	0.0	212	0.0	2.	59	42.	20.	184	41	--	38	12.
March-May (extreme high flows)														
N.	1	1	1	8	8	8	8	8	8	8	8	0	1	8
Min	--	--	--	49	0.0	0.4	4.2	8.8	4.1	47	1.8	--	--	6.5
Max	--	--	--	148	0.0	7.7	46.	37.6	12.	142	29.	--	--	14.5
Mean	--	--	--	80	0.0	1.8	19.	16.4	7.6	72	9.9	--	--	8.8
Med	7.2	180	0.0	61	0.0	0.8	13.	13.	6.7	55	5.1	--	29.9	8.0
June-October (low flows)														
N.	1	4	4	28	25	28	28	28	28	28	28	0	1	28
Min	--	585	0.0	328	0.0	<.05	130	29.	31.	223	99	--	--	5.0
Max	--	761	0.0	624	23.	20.	300	86.	79.	437	293	--	--	25.
Mean	--	640	0.0	489	1.6	3.2	195	65.1	52.2	373	143	--	--	11.3
Med	12.3	607	0.0	495	0.0	2.4	194	67.5	50.	380	138	--	46.8	11.0
June-October (high flows)														
N.														
Min														
Max							NO AVAILABLE DATA							
Mean														
Med														

Table 30. Summary of chemical analyses of water collected from the East Poplar River near Coronach, Canada (above Girard Creek)--nutrients and other constituents. (Discharge data are not available for this site; flow classifications are based on East Poplar discharges at the international boundary.)

Stat	TN	TK_jN	TON	NH_3N	NO_xN	TP	OP	COD	F	Si	B-D	D-Fe	T-Fe
November-February													
N.	0	2	0	10	11	10	10	9	1	10	0	0	9
Min	--	1.91	--	0.38	0.03	0.01	<.01	10.1	--	7.9	--	--	0.28
Max	--	2.4	--	1.2	0.67	0.12	0.02	130.	--	16.3	--	--	2.2
Mean	--	2.16	--	0.73	0.20	0.05	<.01	34.6	--	12.7	--	--	0.97
Med	--	2.16	--	0.67	0.10	0.04	<.01	21.4	0.3	13.	--	--	0.88
March-May (low flows)													
N.	0	2	0	18	18	18	18	16	0	16	0	0	18
Min	--	0.7	--	<.05	<.02	0.02	<.01	11.3	--	3.5	--	--	0.11
Max	--	1.2	--	1.1	0.38	0.37	0.12	61.	--	10.0	--	--	1.4
Mean	--	0.95	--	0.34	0.12	0.12	<.02	24.2	--	6.9	--	--	0.48
Med	--	0.95	--	0.12	0.10	0.11	<.01	21.4	--	6.8	--	--	0.39
March-May (high flows)													
N.	0	2	0	10	12	12	11	11	1	12	0	0	11
Min	--	0.9	--	0.08	0.04	0.06	0.01	28.	--	6.4	--	--	0.15
Max	--	0.9	--	1.95	0.25	0.31	0.14	70.	--	12.8	--	--	1.4
Mean	--	0.9	--	0.91	0.16	0.17	0.05	46.3	--	9.7	--	--	0.61
Med	--	0.9	--	0.95	0.16	0.17	0.04	46.	0.3	10.0	--	--	0.52
March-May (extreme high flows)													
N.	0	1	0	7	5	8	7	7	1	8	0	0	7
Min	--	--	--	0.6	0.03	0.13	0.03	29.	--	2.6	--	--	0.54
Max	--	--	--	2.0	0.53	0.45	0.11	76.	--	7.9	--	--	1.15
Mean	--	--	--	1.06	0.25	0.26	0.08	47.6	--	5.0	--	--	0.81
Med	--	1.0	--	0.9	0.22	0.21	0.08	42.	0.1	4.6	--	--	0.74
June-October (low flows)													
N.	0	4	0	27	28	28	27	24	1	25	0	0	28
Min	--	<.3	--	0.04	<.01	0.02	<.01	7.4	--	2.6	--	--	0.05
Max	--	3.0	--	1.3	0.35	0.34	0.06	32.8	--	9.6	--	--	1.1
Mean	--	1.4	--	0.43	0.10	0.08	<.015	14.9	--	5.8	--	--	0.37
Med	--	1.15	--	0.32	0.09	0.06	<.01	14.4	0.0	5.8	--	--	0.25
June-October (high flows)													
N.													
Min													
Max				NO AVAILABLE DATA									
Mean													
Med													

high flow periods of March-May, these variables were not at adequate concentrations to be suggestive of marked municipal pollution reaching the river. The sharp declines in ammonia levels at the Scobey station indicate that a major portion of this variable's concentration in the East Poplar is probably derived from natural sources originating within its headwaters area in Canada. Nevertheless, ammonia levels in the Coronach samples were generally similar to those obtained at the IB (Table 20), and the concentrations of ammonia at these two locations were at adequate levels to point to possible ammonia toxicity problems in the upper reaches of the river. This potential problem has been discussed previously with reference to the IB station. However, ammonia toxicities might be less of a factor in the Coronach reach than in the border segment as a result of the lower upstream pH values, and as noted previously, this problem is largely dissipated in the lower reach of the East Poplar near Scobey (Table 26) as a result of this station's comparatively low ammonia concentrations. Biotic uptake and oxidation plus atmospheric loss could account for the marked downstream decline in this constituent between the United States-Canadian border and Scobey.

In addition to ammonia's potential toxicity, this constituent, along with nitrite and nitrate, can also contribute to the eutrophic potential of a stream by adding to its total inorganic nitrogen (TIN) levels, as has been described previously. Concentrations of NO_XN in the East Poplar River were generally similar between the Coronach and the IB samples (Tables 20 and 30), although they did tend to decline to some degree in a downstream direction during the low flow periods with this decline, like that for ammonia, most pronounced from the border to the Scobey sampling location. During the high flow stages of spring, however, NO_XN levels appeared to increase to some extent from Coronach to the river's mouth. At the Coronach station (Table 30), mean and median NO_XN concentrations were nearly equivalent through the various low flow seasons, equalling approximately 0.10 mg N/l, with about a two-fold increase in these statistics occurring during the spring high flow phase in response to the inputs of overland flow at this time with its high nutrient loads. Total phosphorous and orthophosphate concentrations also increased by a significant amount during this runoff period. But regardless of this spring increase in NO_XN levels, this constituent in the Coronach samples was not in excess of the lower reference criterion for nitrogen eutrophication (0.35 mg N/l) in very many instances, and none of the samples' NO_XN concentrations exceeded the upper criterion for nitrogen established by the Environmental Protection Agency (68). On the basis of nitrite-nitrate alone, therefore, the East Poplar in Canada would not be diagnosed as eutrophic, but ammonia-nitrogen concentrations also have to be considered in this regard.

As indicated in Table 30, ammonia levels were typically greater than those observed for NO_XN; thus, if the ammonia-nitrogen values are also considered in terms of eutrophy and the TIN variable defined earlier, then the concentrations of nitrogen in the Coronach samples were much more commonly in excess of the two reference criteria for this nutrient. For example, during the biologically active and critical warm weather months of March to October, about 62% of the samples had TIN concentrations in excess of 0.35 mg N/l while only 20% of the samples had TIN levels greater than the high reference criterion for nitrogen. These percentages for the cold weather period were considerably higher, 100% and 49% respectively, and this feature is possibly indicative of the general reductions in biological activity that are experienced under the lower temperatures of the winter season. In any event, these percentages plus the

fact that the mean and median concentrations of TIN were typically greater than the lower nitrogen criterion would indicate that this nutrient was in adequate concentrations in the Coronach segment of the East Poplar to be suggestive of eutrophic conditions for a major portion of the year. Since the mean and median percent contributions of ammonia to the segment's TIN levels equalled 79% and 81%, this would suggest that ammonia is also a critical water quality parameter in the upper East Poplar from the standpoint of stream eutrophy in addition to having potential toxic effects.

As observed for that portion of the East Poplar River in Montana, orthophosphate concentrations in the Coronach segment, except for those during the runoff periods, were again largely negligible with the bulk of the stream's phosphorus tied-up in a combined or total form (TP). For the most part, phosphorous concentrations were generally similar between the three sampling locations on the river, although TP concentrations did appear to decline somewhat downstream during the low flow stages of November to May with slightly higher levels of this nutrient near Coronach in these months; but TP concentrations also tended to increase slightly towards Scobey during the spring runoff phase and during the low flows of summer with slightly lower TP values upstream. However, these downstream changes in phosphorus were neither as distinct nor as consistent as those that have been noted for nitrogen.

In spite of the slightly higher TP levels near Coronach during the cold weather period, the data in Table 30 suggest that this segment of the river, like the IB reach, was largely phosphorous limited and non-eutrophic at this time with the season's median TP concentration located below the lower reference criterion for this nutrient. In turn, although TP levels were slightly lower upstream during the critical warm weather season, mean and median TP concentrations were still above the lower reference level for phosphorus and thereby suggestive of eutrophic conditions. In addition and except for the winter season, a large percentage of the individual samples from the Coronach site had phosphorous levels in excess of its reference criteria as follows:

Season-Flow	<0.05 mg P/l	>0.05 mg P/l	>0.10 mg P/l
November-February, low	70%	30%	10%
March-May, low	17%	83%	56%
March-May, high	0%	100%	90%
June-October, low	39%	61%	29%
Annual (time weighted)	42%	58%	32%

Since the mean and median inorganic nitrogen concentrations of the Coronach samples, in addition to those for phosphorus, were also greater than this nutrient's lower reference criterion, the upper reach of the East Poplar River might be classified as eutrophic but with a reduced degree of predictive success in view of the fact that these statistical values for nitrogen and phosphorus were not in excess of their upper reference levels (68). Furthermore, only a small percentage of the samples (about 11%) collected from the Coronach location during the March to October period would be expected to have both of these nutrients at levels greater than their upper reference criteria. These nutrient data also indicate that the East Poplar is probably more N- than P-limited throughout its length, except for the winter season, with mean and median phosphorous concentrations as TP during the warm weather, March to October season near Coronach further above its lower reference criteria (about 1.9-times) than the case for nitrogen as TIN (about 1.5-times). In addition, TP concentrations

at the Coronach station were also in excess of the lower and upper criteria for phosphorus in a higher percentage of the samples (79% and 55%) than was observed for TIN in the same collections (62% and 20%). Comparing the sets of nutrient data for the three East Poplar sampling stations (Tables 20, 26, and 30), the stream apparently becomes less eutrophic (non-eutrophic near Scobey) and more N-limited in a downstream direction as a result of the marked downstream declines in TIN concentrations in the face of relatively minor instream alterations in the phosphorous variable between Coronach and Scobey. For the most part, therefore, it does not appear that the East Poplar is degraded in an aesthetic sense to any significant degree in terms of excessive stream eutrophication, and this conclusion is most applicable to the Montana reach of the river.

Along with the nutrient information, data for COD, fluoride, and silica are also summarized in Table 30 for the East Poplar near Coronach, Canada. However, no analyses were made for dissolved boron and iron by the Canadian agencies that had been sampling at this stream location, and the data that was collected for total recoverable (TR) iron will be discussed later in this report.

As indicated in Table 30, neither COD, fluoride, nor silica are suggestive of water quality problems in the extreme upper reach of the East Poplar River. Although the COD concentrations of the Coronach samples were also indicative of greater organic levels in the waters of the Canadian reach, as has been described earlier, with somewhat higher COD values at this location than at the IB site (except for the summer season), these slightly higher COD levels were again most similar to those that are obtained from unpolluted and natural waters since COD's approaching 250 mg/l can be commonly obtained from mildly polluted systems (89). As observed for the border station, both the COD and the color levels of Coronach waters increased during the high flow period, but this increase was probably in response to natural organic inputs (e.g., humic acid) via overland flow.

Like the case for COD, the concentrations of both fluoride and silica were also nondistinctive in the East Poplar; fluoride was representative of an insignificant ionic component of the stream samples with concentrations well below the reference level for aquatic biota (Table 15). Although silica concentrations were considerably higher than those for fluoride, they were either nearly equal to or less than the median value that has been calculated for the nation's surface waters (83). Similar to the Montana reach of the river, mean and median silica levels in the Canadian segment also demonstrated a seasonal decline from the biologically dormant winter season to the active warm weather period of June to October, but these declines at Coronach (54% and 55%) were less distinct than those observed for the two downstream sites, i.e., 77% and 76% at the international boundary and 87% and 84% near Scobey. Thus, silica was not at adequately high or low levels to be toxic or limiting to the river's phytophyton near Coronach.

Metals and miscellaneous constituents.

Results of metal analyses from the Coronach samples are presented in Table 31 along with small amounts of data for total inorganic carbon (TOC) and chlorophyll. The TOC levels of the extreme upper reach of the East Poplar were very close to those that are typically obtained from unpolluted waters (87), and

Table 31. Summary of chemical analyses of water collected from the East Poplar River and Girard Creek near Coronach, Canada--metals and miscellaneous constituents.

East Poplar River

Stat	T-Ag	T-Al	D-As	T-B	T-Ba	T-Cd	T-Cr	T-Cu	T-Hg
N.	1	2	2	3	4	4	2	66	30
Min	--	0.025	0.002	0.94	<.05	<.001	<.015	<.001	<.00005
Max	--	0.65	0.002	1.18	0.13	0.002	<.015	0.04	0.00124
Mean	--	0.338	0.002	1.07	<.075	<.001	<.015	<.01	<.00015
Med	<.04	0.338	0.002	1.1	<.06	<.001	<.015	<.01	<.00005

Stat	T-Mo	T-Mn	T-Pb	D-Se	T-Zn	TOC	Chl (ug/l)
N.	1	72	25	2	66	10	5
Min	--	<.01	<.004	<.0005	<.001	4.	12.
Max	--	0.53	0.03	<.0005	0.14	22.	39.2
Mean	--	0.11	<.02	<.0005	<.02	12.6	20.8
Med	<.10	0.08	<.02	<.0005	0.01	12.	17.

Girard Creek--Outlet from Coronach Town Reservoir

Stat	T-Cu	T-Hg	T-Mn	T-Pb	T-Zn
N.	37	6	37	13	37
Min	<.01	<.00005	0.03	<.02	<.01
Max	0.02	0.00026	0.18	0.05	0.29
Mean	<.01	<.00011	0.08	<.025	<.03
Med	<.01	<.00009	0.07	<.02	0.01

Girard Creek--Inlet from Coronach Town Reservoir

Stat	T-Cu	T-Hg	T-Mn	T-Pb	T-Zn
N.	24	1	24	13	24
Min	<.01	--	0.01	<.02	<.01
Max	0.03	--	0.14	0.02	0.08
Mean	<.013	--	0.05	<.02	0.03
Med	<.01	0.00011	0.04	<.02	0.03

these results thereby tend to confirm the previous observations that the East Poplar is largely unaffected by man-related organic inputs reaching the stream. Mean and median chlorophyll values from the Canadian reach were somewhat higher than those obtained at the IB site (Table 22), and this is suggestive of slightly higher levels of primary production upstream as is implied by the nutrient data. But as noted earlier, the chlorophyll concentrations at both the Coronach and IB stations were not significantly greater than those that have been obtained from mildly productive lakes in Montana (81, 97). This parameter, like the nutrient information, therefore, does not point to the occurrence of severely eutrophic conditions in the river at the present time.

As indicated in Table 31, a more restricted spectrum of metals was analyzed by the Canadian agencies for the Coronach sampling station than was the case downstream, and these analyses were primarily obtained in the total recoverable form. Thus fewer conclusions can be drawn in this regard for the Canadian reach than for the Montana segment. However, fairly large numbers of analyses are available for five of the trace elements (copper, mercury, manganese, lead, and zinc), and some definite conclusions can be derived for these constituents in relation to their TR concentrations. The data that have been collected for Mn and Pb, along with that for As, B, Ba, Cd, Cr, Mo, and Se, indicate that these nine trace elements were not representative of water quality problems in the East Poplar with their dissolved (D) or TR levels below the respective reference criteria for aquatic biota in all of the samples (Table 15). This also probably applies to Cu and Zn with the TR levels of only a few samples slightly in excess of the criteria for these metals. The TR/D ratios defined earlier for Cu and Zn (both equal to 2.0) indicate that only about 13% of the Coronach samples would have had dissolved levels of either Cu or Zn in excess of the minimal risk levels, and only 1.5% of the samples would have been suggestive of hazardous conditions in relation to these two metals. In addition, the mean and median dissolved concentrations of both of these constituents would have been well below their critical concentrations. As a result, of the trace elements analyzed for the extreme upper East Poplar, only iron (Table 30) and mercury (Table 31) appear to have been in adequate concentrations to potentially degrade the quality of the stream. No conclusions of this kind can be made for the status of silver because of the inadequate detection limits that were applied to the single sample analyzed for this variable. In the case of aluminum, its high TR/D ratio of 15 indicates that its dissolved concentrations, equalling less than 0.05 mg/l, would have been well below the corresponding reference level and thereby unsuggestive of water quality problems, as has been observed for the IB location.

No consistent and yearlong changes in TR-Fe levels became evident in the East Poplar from Coronach to the international boundary (Tables 20 and 30), although iron concentrations were obviously lower at the border station during the winter season with higher maximum and mean TR concentrations downstream during the spring runoff period. For the remainder of the low flow year, however, TR-Fe levels were closely similar between the two sampling locations, and this latter observation can also be generally applied to the other metals analyzed in the Coronach samples. These features are suggestive of nondistinctive metals concentrations in the base-flow input waters to the river between Coronach and Scobey. The high iron levels that were obtained during the high flows of spring were probably associated with the inputs of suspended sediment at this time from overland flow.

As illustrated in Table 30, the mean and median TR concentrations of iron were typically in excess of this metal's reference criterion with a large percentage of the Coronach samples having TR concentrations greater than 0.2 mg/l, indicative of possible water quality problems. However, a much smaller percentage of the samples would have had dissolved (D) levels in excess of this criterion due to the D < TR relationship. Using the TR/D ratio established previously for iron, i.e., >4.0 with an 89% level of confidence, the maximum dissolved mean and median concentrations of this metal can be estimated for the Coronach samples with a fair degree of reliability as follows:

	Winter (low flows)	Spring (low flows)	Spring (high flows)	Spring (extreme high flows)	Summer (low flows)
Mean	0.24	0.12	0.15	0.20	0.09
Median	0.22	0.10	0.13	0.19	0.06

As indicated above, the mean and median levels of D-Fe in the Coronach samples, with the possible exception of those during the winter, probably would have been below this metal's freshwater reference criterion, and only slightly greater mean-median concentrations over this criterion (about 1.15-times) would have been obtained for the cold weather season. In turn, less than 23% of the Coronach collections would have had D-Fe levels greater than its freshwater reference value with only 5% of the samples having iron at hazardous concentrations. These results, therefore, indicate that the current iron concentrations of the extreme upper river are most suggestive of only occasional problems in the stream, which is in accord with the conclusion that was derived for the IB station. But like the case for ammonia, such potential iron problems in the river appear to be largely absent from the East Poplar waters once they have reached the Scobey station (Table 26).

The median TR concentration of mercury in the Coronach samples (Table 31) was below the average reference criterion for this parameter (0.05 ug/l) (24), although no conclusions of this kind can be drawn for its mean concentration due to the inadequate detection limits of most of the analyses. Nevertheless, the high maximum TR value of mercury indicates that this parameter did violate its grab sample criterion on occasion (0.2 ug/l)(in about 13% of the cases), and as a result, mercury appeared to be at adequate levels to sporadically degrade the quality of the stream. But like the case for iron, this would not be classified as a continuous problem. In view of these discussions, both iron and mercury might be viewed as critical water quality parameters in the East Poplar River in relation to any impacts emanating from the Coronach development; that is, any future increases of these constituents in the stream in response to the development would greatly enhance these element's natural penchant for degrading the river's quality of water. Manganese might also be added to this list because of its relatively high, pre-development concentrations. As noted previously, however, the other metals, regardless of their low concentrations at the present time, should not be ignored in this regard since only slight additions of these elements to the river by some impact source, i.e., on the order of 0.03 mg/l to 0.5 mg/l, would be necessary to afford fairly significant water quality degradations.

Girard Creek near Coronach

Field parameters and dissolved solids.

"Field" parameter data for the inlet and outlet of the Coronach town reservoir on Girard Creek are summarized in Table 32. No data are available at these sites for DO, BOD, and the coliforms, so no conclusions can be drawn for the pollution status of the stream with reference to this table. However, it might be assumed from the previous discussions that Girard Creek, like the East Poplar River, is generally unpolluted at the present time. Some COD data have been collected from the stream which can be utilized to check this assumption, and this information will be discussed later in this report. In addition, no statements can be made concerning the flow and temperature characteristics of the stream, but again it might be assumed from the discharge and temperature data at the IB that Girard Creek, like the upper East Poplar, is also a relatively small stream with either B-D_2 or B-D_3 temperature characteristics.

Data in Table 32 indicate that the qualities of samples from Girard Creek were essentially similar between the reservoir's inlet and outlet waters. The only major difference between the two sites was found in the slightly higher color levels of the inlet waters during the June-October period with the inflow waters somewhat colored at this time; outside of this occurrence, the color of the Girard Creek samples would be barely noticeable by the human eye (32). Otherwise, values of pH, turbidity, and DS-SC were also generally similar between the upper and lower stations, indicating that the impoundment apparently had a relatively minor effect on the stream. Possibly this small reservoir lacked an adequate volume and retention time to afford the requisite evaporative losses that would be necessary to significantly concentrate the dissolved constituents in the stream below the dam.

One of the most distinctive water quality attributes of the Girard Creek samples was found in their high pH values at both sampling locations (Table 32) with the high extremes well in excess of those obtained from the East Poplar at the IB (Table 17). Many of these high pH values, particularly those during the warm weather season, were above the fishery limit established by the State of Montana (44), and they were well above the upper limit deemed desireable for a good fishing water (88). Thus, this variable could very well negate the establishment of a resident sport fish population in the creek. The development of such high pH values might be suggestive of a highly productive stream, as has been noted earlier. However, although values of pH were lower in Girard Creek under the reducing conditions of winter than during the summer, they were still relatively high in relation to the cold weather values that were monitored at the other sampling locations in the drainage; and this feature plus the distinctively high extremes of pH that were obtained for the two Girard stations would indicate that other factors, in addition to the aquatic biota, were influencing the status of this variable the stream.

In contrast to pH, the DS-SC levels of Girard Creek were nondistinctive and comparatively low at both sampling stations, and this non-saline characteristic was most pronounced during the 1974 high water year which had an average yearly discharge of 24,571 AF at the IB (55). The 1973 low water year had much higher DS-SC levels than those of the following year, between 1.8- and 2.0-times, with a significantly lower average yearly discharge of 4,033 AF at the IB gaging station (55). The DS-SC levels in Girard Creek were somewhat less than those in

Table 32. Summary of chemical analyses of water collected from Girard Creek near Coronach, Canada--field parameters and dissolved solids. (Flow data are not available for this stream; data classifications, if made, are based on month and year.)

Outlet from Coronach Town Reservoir

Stat	Flow	Temp	pH	Clr	Turb	TSS	SC	DS	DO	%Sat	BOD	TC	FC
November-February (1973 plus 1974)													
N.	0	0	3	3	3	0	3	3	0	0	0	0	0
Min	--	--	8.05	10	3.5	--	710	544	--	--	--	--	--
Max	--	--	9.17	10	6.6	--	1140	724	--	--	--	--	--
Mean	--	--	8.61	10	4.9	--	853	604	--	--	--	--	--
Med	--	--	8.60	10	4.7	--	710	545	--	--	--	--	--
March-May (1973)													
N.	0	0	10	10	10	0	10	10	0	0	0	0	0
Min	--	--	7.81	<5	2.8	--	640	521	--	--	--	--	--
Max	--	--	8.80	15	57.5	--	1015	670	--	--	--	--	--
Mean	--	--	8.48	<6	14.5	--	819	613	--	--	--	--	--
Med	--	--	8.64	<5	9.4	--	823	617	--	--	--	--	--
June-October (1973)													
N.	0	0	14	14	14	0	14	14	0	0	0	0	0
Min	--	--	8.60	5	4.4	--	861	508	--	--	--	--	--
Max	--	--	9.55	30	87.0	--	1280	718	--	--	--	--	--
Mean	--	--	9.04	17	21.7	--	1029	641	--	--	--	--	--
Med	--	--	9.08	15	12.	--	1040	645	--	--	--	--	--
June-October (1974)													
N.	0	0	10	10	10	0	10	10	0	0	0	0	0
Min	--	--	8.76	<5	3.7	--	345	188	--	--	--	--	--
Max	--	--	9.25	30	43.	--	620	454	--	--	--	--	--
Mean	--	--	9.02	15	15.8	--	506	339	--	--	--	--	--
Med	--	--	9.00	15	13.	--	525	365 (1073?)	--	--	--	--	--

Inlet to Coronach Town Reservoir

Stat	Flow	Temp	pH	Clr	Turb	TSS	SC	DS	DO	%Sat	BOD	TC	FC
March-May (1973)													
N.	0	0	10	10	10	0	10	10	0	0	0	0	0
Min	--	--	7.49	<5	2.5	--	659	455E	--	--	--	--	--
Max	--	--	8.84	25	29.0	--	1227	820	--	--	--	--	--
Mean	--	--	8.47	<8	15.4	--	884	665	--	--	--	--	--
Med	--	--	8.60	<5	11.9	--	794	710	--	--	--	--	--
June-October (1973)													
N.	0	0	14	14	14	0	14	14	0	0	0	0	0
Min	--	--	8.70	20.	4.1	--	1000	738	--	--	--	--	--
Max	--	--	9.93	50.	57.5	--	1480	893	--	--	--	--	--
Mean	--	--	9.41	30.	14.6	--	1201	815	--	--	--	--	--
Med	--	--	9.43	27.5	8.5	--	1189	800	--	--	--	--	--

the East Poplar River, and this factor coupled with the relatively low turbidity and color values is suggestive of an excellent and aesthetically pleasing class of fishery in the tributary that is less marginal in nature than that in the mainstem per se. But as noted, the high pH levels of Girard Creek would definitely detract from this characterization.

Common constituents.

As indicated in Table 33, the waters of Girard Creek, like the rest of the East Poplar drainage, were typically very hard even though its calcium and magnesium concentrations and its total hardness levels were somewhat lower than those of the East Poplar River near Coronach (Table 29). The Girard Creek samples were also significantly less alkaline than those collected from the East Poplar mainstem, with lower total alkalinities (TA), although phenolphthalein (PA) values were comparatively high in the tributary as a result of the high pH levels. Such comparatively low calcium and bicarbonate concentrations in Girard Creek may have been reflective of a $CaCO_3$ precipitation in response to these high pH values. Nevertheless, bicarbonate was still the dominant anion in the stream, and since sodium was the dominant cation, the Girard Creek waters are probably best classified as being sodium bicarbonate in character. However, sulfate was also an abundant ionic constituent with its concentrations generally similar to those of the upper East Poplar. In view of the comparatively low bicarbonate levels, Girard Creek was much more sodium sulfate in nature than the East Poplar near Coronach with generally lower and higher HCO_3/SO_4 and Na/(Ca + Mg) ratios respectively. As a result, the input of Girard Creek waters to the East Poplar could account, at least in part, for the downstream changes in mainstem ionic compositions wherein the main river becomes more sodium sulfate in nature from Coronach to Scobey. Relative to sodium, calcium and magnesium were representative of secondary cationic constituents that demonstrated roughly equal concentrations in the tributary samples, and potassium and chloride were again indicative of insignificant components in the drainage waters.

The inflow and outflow of the Coronach town reservoir were largely similar in their calcium, magnesium, total hardness, potassium, and chloride levels, although the inlet samples did tend to have slightly higher TA, PA, sulfate, sodium, and DS-SC concentrations than the outlet waters. In both instances, however, common constituent concentrations did not appear to be at adequate levels to adversely effect the aquatic biota of the stream and reservoir.

Nutrients and other constituents.

Both the concentrations of silica and total recoverable iron in the Girard Creek samples (Table 34) were typically lower than those in the East Poplar River. This aspect was particularly obvious in relation to the silica values of the reservoir inflow waters, and silica concentrations at both of the stations were well below this parameter's national average (83) and generally below the statewide average for Montana's streams (12). In a few of the samples, silica was at low enough levels to be limiting to diatom development, but for the most part, silica was in sufficient concentrations so as not to be an affecting factor in this regard (80). In contrast to silica, TR-Fe levels were generally similar between the reservoir's inflow and outflow, and due to the low concentrations of this constituent, iron was also unsuggestive of water quality problems in Girard Creek. This stands in contrast to the occasional

Table 33. Summary of chemical analyses of water collected from Girard Creek near Coronach, Canada--common constituents. (Flow data are not available for this stream; data classifications, if made, are based on month and year.)

Outlet from Coronach Town Reservoir

Stat	CO_2	HCO_3	CO_3	TA	PA	Cl	SO_4	Ca	Mg	TH	Na	SAR	%Na	K
November-February (1973 plus 1974)														
N.	0	0	0	3	3	3	3	3	3	3	3	0	0	3
Min	--	--	--	228	14	3.9	169	15.	29.	178	106	--	--	13.
Max	--	--	--	412	54	5.5	232	31.	40.	202	203	--	--	14.
Mean	--	--	--	301	28	4.6	194	23.3	32.7	192	144	--	--	13.3
Med	--	--	--	262	16	4.3	181	24.	29.	196	123	--	--	13.
March-May (1973)														
N.	0	0	0	10	10	10	10	10	10	10	10	0	0	10
Min	--	--	--	312	0.0	0.3	96	28.	35.	224	42	--	--	14.3
Max	--	--	--	325	24.	1.5	186	63.	44.	331	112	--	--	23.5
Mean	--	--	--	318	13.	0.9	119	46.3	42.8	275	69	--	--	19.1
Med	--	--	--	317	13.	1.0	108	48.5	38.	287	62	--	--	18.2
June-October (1973)														
N.	0	0	0	14	14	14	14	14	14	14	14	0	0	14
Min	--	--	--	326	18	<.3	156	12.	29.	150	128	--	--	14.5
Max	--	--	--	404	90	6.8	248	30.	54.	257	197	--	--	21.3
Mean	--	--	--	365	47	4.1	207	19.0	36.6	199	165	--	--	17.2
Med	--	--	--	361	44	4.0	215	17.5	36.	192	162	--	--	16.5
June-October (1974)														
N.	0	0	0	10	10	10	10	10	10	10	10	0	0	10
Min	--	--	--	124	13	0.5	50	16.	13.	102	33	--	--	8.0
Max	--	--	--	222	42	3.1	158	25.	32.	190	95	--	--	14.
Mean	--	--	--	185	26	1.7	107	19.7	23.0	143	73	--	--	11.0
Med	--	--	--	200	22	1.5	115	19.	22.5	141	83	--	--	11.

Inlet to Coronach Town Reservoir

Stat	CO_2	HCO_3	CO_3	TA	PA	Cl	SO_4	Ca	Mg	TH	Na	SAR	%Na	K
March-May (1973)														
N.	0	0	0	10	10	10	10	10	10	10	10	0	0	10
Min	--	--	--	219	0.0	<.3	95	28.	23.	170	56	--	--	13.3
Max	--	--	--	388	30.	1.0	387	55.	45.	307	220	--	--	21.8
Mean	--	--	--	326	14.	0.5	207	41.1	37.8	259	124	--	--	17.8
Med	--	--	--	330	15.	0.5	177	42.	39.	272	101	--	--	18.0
June-October (1973)														
N.	0	0	0	14	14	14	14	14	14	14	14	0	0	14
Min	--	--	--	378	30	<.3	192	8.	33.	156	190	--	--	13.5
Max	--	--	--	482	136	7.6	331	30.	47.	246	240	--	--	21.5
Mean	--	--	--	420	92	4.8	249	16.1	39.4	201	214	--	--	17.1
Med	--	--	--	406	91	4.4	244	15.	39.	193	212	--	--	17.0

Table 34. Summary of chemical analyses of water collected from Girard Creek near Coronach, Canada--nutrients and other constituents. (Flow data are not available for this stream; data classifications, if made, are based on month and year.)

Outlet from Coronach Town Reservoir

Stat	TN	TK_jN	TON	NH_3N	NO_XN	TP	OP	COD	F	Si	D-B	D-Fe	T-Fe
November-February (1973 plus 1974)													
N.	0	0	0	3	3	3	3	3	0	3	0	0	3
Min	--	--	--	0.55	0.02	0.05	<.01	30	--	4.	--	--	0.01
Max	--	--	--	0.93	0.10	0.34	0.02	84	--	7.9	--	--	0.40
Mean	--	--	--	0.69	0.06	0.17	<.01	53	--	6.4	--	--	0.19
Med	--	--	--	0.6	0.06	0.12	0.01	45	--	7.2	--	--	0.15
March-May (1973)													
N.	0	0	0	10	10	10	10	10	0	10	0	0	10
Min	--	--	--	0.07	0.07	0.09	<.01	30.0	--	1.7	--	--	0.13
Max	--	--	--	0.18	0.14	0.65	0.17	35.2	--	3.7	--	--	2.4
Mean	--	--	--	0.13	0.11	0.43	<.05	32.8	--	2.7	--	--	0.47
Med	--	--	--	0.12	0.12	0.43	<.01	32.5	--	2.8	--	--	0.24
June-October (1973)													
N.	0	0	0	14	14	14	14	14	0	14	0	0	14
Min	--	--	--	0.14	0.04	0.11	<.01	32.3	--	1.8	--	--	0.01
Max	--	--	--	1.3	0.15	0.57	0.06	74.4	--	6.9	--	--	0.61
Mean	--	--	--	0.47	0.10	0.34	<.02	50.9	--	4.3	--	--	0.24
Med	--	--	--	0.46	0.10	0.29	<.01	47.0	--	4.15	--	--	0.135
June-October (1974)													
N.	0	0	0	10	10	10	10	10	0	10	0	0	10
Min	--	--	--	0.3	<.01	0.05	<.01	4.	--	0.1	--	--	<.02
Max	--	--	--	1.6	0.22	0.39	0.04	61.	--	12.0	--	--	0.55
Mean	--	--	--	0.77	0.08	0.20	<.013	38.1	--	6.7	--	--	0.16
Med	--	--	--	0.55	0.06	0.18	0.01	33.	--	8.1	--	--	0.14

Inlet to Coronach Town Reservoir

Stat	TN	TK_jN	TON	NH_3N	NO_XN	TP	OP	COD	F	Si	D-B	D-Fe	T-Fe
March-May (1973)													
N.	0	0	0	10	10	10	10	10	0	10	0	0	10
Min	--	--	--	0.07	0.09	0.12	<.01	27.6	--	1.2	--	--	0.16
Max	--	--	--	0.13	0.17	0.62	0.16	41.2	--	2.3	--	--	1.1
Mean	--	--	--	0.10	0.12	0.39	0.04	34.3	--	1.8	--	--	0.43
Med	--	--	--	0.10	0.11	0.39	0.035	34.7	--	1.8	--	--	0.28
June-October (1973)													
N.	0	0	0	14	14	14	14	14	0	14	0	0	14
Min	--	--	--	0.15	0.05	0.14	<.01	42.3	--	0.3	--	--	<.01
Max	--	--	--	1.55	0.21	0.53	0.06	71.3	--	4.8	--	--	0.92
Mean	--	--	--	0.55	0.10	0.34	<.02	55.3	--	2.3	--	--	0.20
Med	--	--	--	0.465	0.10	0.36	<.01	55.2	--	2.55	--	--	0.125

iron problems forecast for the upper East Poplar River. Using the TR/D ratio for iron defined previously, only about 6.5% of the Girard Creek samples would be expected to have dissolved iron in excess of its freshwater criteria (41) whereas about 23% of the East Poplar-Coronach and 12% of the East Poplar-IB samples were projected to have D-Fe at levels greater than this reference value. As noted previously, iron did not appear to be a significant problem in the extreme lower reach of the mainstem river near Scobey.

Like silica and iron, COD and phosphorous levels in Girard Creek (Table 34) were also somewhat distinct in relation to the East Poplar River, but in this case, this distinction was due to the higher concentrations of these variables in the tributary's inflow and outflow samples than in the mainstem collections. As noted for the East Poplar near Coronach, the high COD's in Girard Creek also pointed to the occurrence of higher organic concentrations in the upstream reaches of the drainage, but the organics in Girard Creek were also most probably derived from natural sources in the headwaters region, such as from swampy and marshy areas, rather than from pollutive sources. That is, these higher COD concentrations were still at inadequate levels to be indicative of organic pollution reaching the stream, and this was also the case for the creek's ammonia values.

Using the average BOD/COD ratio calculated from the mean and median data for these variables from the East Poplar-IB (0.125) (Tables 17 and 20), mean and median BOD_5 levels in Girard Creek were estimated as ranging from about 4.1 to 6.9 mg/l with a maximum value of about 10.5 mg/l. These statistical values were relatively high in comparison to those obtained from the East Poplar, and they varied around the 5.0 mg/l BOD level that has been purported to cause some degree of deoxygenation in sluggish streams (41). Assuming that Girard Creek is intermittently ponded with slow-moving waters in some locations, as has been observed for the East Poplar (26), then the high COD's of the creek could conceivably couse some oxygen reductions. However, the inter-pond riffle areas might in turn provide for some effective re-aeration which would thereby lower the oxygen depletion effects of the stream's organic materials. In any event, COD and this potential depletion problem do not appear to be of major import to the creek, except possibly for the cold weather, ice-covered seasons, since the stream's estimated BOD_5 levels, including the maximum value, were not that much above those that can be obtained from natural waters (86).

The relatively high concentrations of phosphorus in Girard Creek appear to be much more important from a water quality standpoint than the high levels of COD since the mean and median TP concentrations of the seasonal collections were well above the upper eutrophic criterion for this critical nutrient. About 93% of the samples from both stations through all seasons had TP levels in excess of 0.10 mg P/l while 100% had TP concentrations in excess of 0.05 mg P/l. Therefore, in spite of the relatively low orthophosphate concentrations, which appear to be a typical feature of the East Poplar drainage, the phosphorous levels of Girard Creek in the TP form were indicative of a high probability for stream eutrophy throughout the year, even during the winter season. These results also indicate that the relatively high phosphorous concentrations of the East Poplar River in Montana were probably derived from its Canadian headwaters area via groundwater inputs and via surface water inputs from tributaries such as Girard Creek.

In contrast to TP, levels of NO_xN in Girard Creek were nondistinctive (Table 34) and generally similar to those obtained from the other sampling locations in the East Poplar sub-basin. However, the high ammonia levels that apparently characterize the upper reaches of the East Poplar drainage were also evident in both the inlet and the outlet samples from Girard Creek for a large portion of the year. As a result, mean and median TIN concentrations at both of the sampling sites were typically above the lower nitrogen criterion for eutrophication. The major exception occurred during the March to May period when ammonia and thereby TIN concentrations were relatively low at both of the sampling sites and below this reference value for some unknown reason. But for the rest of the year, both nitrogen and phosphorus were at adequate levels in Girard Creek to be suggestive of eutrophic conditions with this stream more N- than P-limited throughout the year.

In addition to being a potential eutrophic factor, ammonia is also a critical water quality parameter in relation to its potential biotic toxicity, and this feature is particularly important to Girard Creek because of the stream's high ammonia and high pH levels. That is, under the creek's median pH values of 8.6 to 9.0, about 21% to 35% of its total median ammonia levels during the June to February period would be in the unionized and toxic form (24), equalling between 0.13 mg N/l and 0.19 mg N/l; about 0.02 mg N/l of median unionized ammonia would be expected for the stream in the months of March to May. These calculated concentrations are typically above ammonia's reference value of 0.02 mg/l (Table 15). Thus, ammonia appears to be a doubly critical water quality parameter in Girard Creek by affording both eutrophic and toxic effects, and this appears to be a general case throughout the upper portion of the East Poplar sub-basin.

Metals and miscellaneous constituents.

In addition to iron, only five other metals were assessed by the Canadian agencies monitoring the Girard Creek sampling locations, and these constituents were analyzed only in their total recoverable forms. However, considerable quantities of TR data are available for three of these metals as summarized in Table 31.

The TR levels for each of the metals analyzed at the two Girard Creek stations were generally similar to those obtained for the East Poplar near Coronach with a close equivalency in concentrations between the two Girard stations. Based upon the metals' TR/D ratios and the trace element discussions for the East Poplar River presented earlier, it would appear unlikely that any of these metals, with the possible exception of mercury, were in adequate concentrations to afford water quality problems to the stream. Although a great deal of data was not collected for mercury, a few violations of this constituent's grab sample criterion did become evident in the Girard Creek samples, and this feature is indicative of an occasional mercury problem. But these data were insufficient, with inadequate detection limits, to afford a judgement or confirmation of this potential mercury problem in relation to its average criterion (Table 15). For the most part, therefore, the metals, including iron, were non-suggestive of marked water quality and biotic degradations in Girard Creek at the time of sampling. Other factors, such as ammonia and pH, would appear to be much more critical to the creek in this regard than several of the trace elements.

OTHER MAJOR TRIBUTARIES

Middle Fork Poplar River at the International Boundary

Recent water quality data.

Comparatively little in the way of water quality data has been made available for the Middle Fork Poplar River at the international boundary in recent years, i.e., since 1970, since only fifteen sample analyses for this site had been published at the time of this writing. Thus, water quality judgements for this location will be out of necessity less definite than those that have been put forth for the East Poplar-IB. Due to this paucity of data, no attempt was made to flow classify the recent Middle Fork data once the seasonal separations had been made; e.g., no March-May, high flow quality data had been collected from the stream. However, in addition to the post-1970 quality data, some historical, pre-1965 information for the IB location (Table 5) on the Middle Fork was also made available to the State Water Quality Bureau (96); but due to the marked differences in various parametric concentrations between the two sets of data, most of the pre-1965 data, except for many of the trace elements, had to be summarized and tabulated apart from the recent collections. Both the recent and historical water quality summaries of the upper Middle Fork station are included in the same tables of this report: the "field" parameters and dissolved solids in Table 35, common constituents in Table 36, nutrients and other constituents in Table 37, and the metals and miscellaneous constituents in Table 38. The concentrational differences between the post-1970 and pre-1965 sets of data are readily evident in Table 35 through the consistently lower DS-SC levels that were obtained in the collections of the earlier years. These historical data and the possible quality differences between stream samples of different decades will be considered in more detail elsewhere in this Middle Fork discussion.

In many instances, the recent qualities of water in the Middle and East Forks of the Poplar River at the international boundary were quite similar, which might be expected since the two streams drain relatively small and generally contiguous areas in southcentral Saskatchewan. However, some distinct differences also became evident between the two rivers in their quality characteristics, and these differences will be summarized later in this section. The general similarities in their parametric concentrations and in their seasonal concentrational changes are outlined below.

In the case of the "field" parameters (Tables 17 and 35), these water quality similarities between streams can be listed as follows: (I) Both of the streams demonstrated relatively low winter temperatures approaching 0.0 C which is suggestive of ice-cover at this time, and both of the rivers had a marked warming trend into the spring and summer seasons with these temperatures most appropriate for either a warm water or a marginal cold water fishery (44). (II) Seasonal levels of pH were also generally similar in the samples from the two rivers. In both cases, pH values were relatively low under the ice-covered and reducing conditions of winter, and marked increases of pH were obtained during the warm weather months possibly in response to the enhanced biotic activities of the spring-summer period. In both streams, the high extremes of pH, like temperature, were most suggestive of a warm water, $B\text{-}D_3$, or a marginal cold water, $B\text{-}D_2$, fishery (Table 7); minimum levels of pH were nondistinctive in either stream. (III) The Middle Fork, like the East

Table 35. Summary of chemical analyses of water collected from the Middle Fork Poplar River at the international boundary (recent and historical data)--field parameters and dissolved solids.

Recent (Post-1970) Data

Stat	Flow	Temp	pH	Clr	Turb	TSS	SC	DS	DO	%Sat	BOD	TC	FC
November-February													
N.	3	4	4	1	4	1	4	4	4	3	0	2	2
Min	1.6	0.0	7.5	--	2.4	--	850	623	8.4	78	--	67	<1
Max	5.6	2.0	8.3	--	9.	--	1310	898	12.0	95	--	70	26
Mean	3.17	0.7	7.85	--	4.9	--	1093	743	10.4	85	--	69	13
Med	2.3	0.4	7.8	5	4.	10	1105	726	10.6	82	--	69	13
March-May (low flows)													
N.	3	3	3	0	3	0	3	3	3	3	0	3	3
Min	6.9	0.5	8.0	--	2.	--	1100	698	7.2	78	--	<1	<1
Max	9.5	17.0	8.4	--	3.	--	1350	900	10.2	90	--	20	50
Mean	8.1	9.3	8.23	--	2.3	--	1210	779	8.9	83	--	8	18
Med	8.0	10.5	8.3	--	2.	--	1180	740	9.2	82	--	3	2
June-October													
N.	7	8	8	0	7	2	8	8	8	6	0	0	2
Min	0.15	3.0	8.2	--	2.	4.	788	511	4.6	60	--	--	41
Max	61.	25.0	9.1	--	45.	24.	2000	1410	11.4	131	--	--	830
Mean	9.48	17.3	8.59	--	14.1	14.0	1451	985	8.3	100	--	--	436
Med	0.90	19.5	8.50	--	10.	14.	1440	971	8.6	101	--	--	436

Historical (Pre-1965) Data

Stat	Flow	Temp	pH	Clr	Turb	TSS	SC	DS	DO	%Sat	BOD	TC	FC
November-February													
N.	0	2	2	2	2	0	2	2	0	0	0	0	0
Min	--	0.6	8.1	10	0.5	--	771	471	--	--	--	--	--
Max	--	1.7	8.3	15	3.	--	1033	647	--	--	--	--	--
Mean	--	1.2	8.20	13	1.8	--	902	559	--	--	--	--	--
Med	--	1.2	8.2	13	1.8	--	902	559	--	--	--	--	--
March-May (low flows)													
N.	1	1	1	1	1	1	1	1	0	0	0	0	0
Min	--	--	--	--	--	--	--	--	--	--	--	--	--
Max	--	--	--	--	--	--	--	--	--	--	--	--	--
Mean	--	--	--	--	--	--	--	--	--	--	--	--	--
Med	9.8	8.9	8.6	20	6	4.4	978	628	--	--	--	--	--
March-May (high flows)													
N.	3	3	3	3	3	0	3	3	0	0	0	0	0
Min	41.6	0.0	7.9	30	2.	--	334	197	--	--	--	--	--
Max	77.	7.8	8.6	90	5.	--	1028	680	--	--	--	--	--
Mean	55.5	4.8	8.17	60	4.0	--	566	361	--	--	--	--	--
Med	47.8	6.7	8.0	60	5.	--	335	205	--	--	--	--	--
June-October													
N.	6	7	7	7	7	1	7	7	0	0	0	0	0
Min	0.5	1.7	8.2	5	0.2	--	691	418	--	--	--	--	--
Max	5.3	20.0	8.6	20	4.	--	780	469	--	--	--	--	--
Mean	2.30	14.3	8.37	13	1.5	--	679	435	--	--	--	--	--
Med	2.25	15.0	8.4	15	1.	14.4	712	427	--	--	--	--	--

Table 36. Summary of chemical analyses of water collected from the Middle Fork Poplar River at the international boundary (recent and historical data)--common constituents.

Recent (Post-1970) Data

Stat	CO_2	HCO_3	CO_3	TA	PA	Cl	SO_4	Ca	Mg	TH	Na	SAR	%Na	K
November-February														
N.	4	4	4	4	1	4	4	4	3	3	3	2	3	4
Min	4.3	503	0.0	413	--	4.1	104	39.	44.	300	98	3.5	37.3	6.8
Max	28.3	720	0.0	591	--	8.7	210	67.1	45.	350	210	5.1	58.	7.5
Mean	16.4	581	0.0	477	--	6.5	169	52.2	44.4	327	149	4.3	48.4	7.1
Med	16.5	551	0.0	552	0.0	6.6	180	51.5	44.3	330	140	4.3	50.	7.1
March-May (low flows)														
N.	3	2	3	3	0	3	3	3	3	3	3	3	3	3
Min	3.6	523	0.0	429	--	4.9	160	47.	44.	300	150	3.7	51.	7.0
Max	8.4	650	9.	530	--	6.0	240	50.	51.	330	220	5.3	59.	8.3
Mean	5.7	571	3.0	473	--	5.5	200	48.7	46.7	313	177	4.3	54.0	7.8
Med	5.2	540	0.0	460	--	5.7	200	49.	45.	310	160	4.0	52.	8.2
June-October														
N.	6	7	7	7	0	7	7	8	8	7	8	7	6	7
Min	1.1	376	0.0	308	--	0.2	120	25.	26.	180	120	3.9	57.	7.9
Max	7.8	770	62	630	--	14	320	46.	79.5	310	351	8.1	73.	11.
Mean	3.7	598	19	523	--	7.6	231	38.5	46.1	265	249	6.3	65.6	9.2
Med	3.7	607	8	550	--	7.6	240	42.1	44.5	287	255	5.9	66.	8.9

Historical (Pre-1965) Data

Stat	CO_2	HCO_3	CO_3	TA	PA	Cl	SO_4	Ca	Mg	TH	Na	SAR	%Na	K
November-February														
N.	0	2	2	0	0	2	2	2	2	2	2	0	2	2
Min	--	427	0.0	--	--	3.0	81	50.9	46.6	319	54	--	25.2	7.2
Max	--	622	7.0	--	--	3.7	105	80.4	59.3	445	70	--	26.4	7.4
Mean	--	525	3.5	--	--	3.4	93	65.7	53.0	382	62	--	25.8	7.3
Med	--	525	3.5	--	--	3.4	93	65.7	53.0	382	62	--	25.8	7.3
March-May (low flows)														
N.	0	1	1	0	0	1	1	1	1	1	1	0	1	1
Min	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Max	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mean	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Med	--	515	31	--	--	4.6	107	50.8	51.8	340	112	--	41.1	7.4
March-May (high flows)														
N.	0	3	3	0	0	3	3	3	3	3	3	0	3	3
Min	--	175	0.0	--	--	1.4	16	28.0	18.0	144	11	--	12.8	5.4
Max	--	530	11.	--	--	4.0	153	55.2	53.4	359	115	--	40.3	9.5
Mean	--	306	3.7	--	--	2.4	67	39.3	29.9	221	46	--	22.9	7.4
Med	--	212	0.0	--	--	1.9	32	34.7	18.0	161	13	--	15.6	7.4
June-October														
N.	1	7	7	1	1	7	7	7	7	7	7	1	7	7
Min	--	327	0.0	--	--	1.3	73	27.6	45.1	256	32	--	26.5	6.0
Max	--	396	25	--	--	3.3	86	46.2	50.2	306	79	--	39.2	7.7
Mean	--	373	15	--	--	2.5	79	33.3	46.9	276	45	--	31.0	6.8
Med	2	379	17	325	0.0	2.7	78	32.0	46.3	268	56	1.3	30.2	6.8

Table 37. Summary of chemical analyses of water collected from the Middle Fork Poplar River at the international boundary (recent and historical data)--nutrients and other constituents.

Recent (Post-1970) Data

Stat	TN	TK_jN	TON	NH_3N	NO_xN	TP	OP	COD	F	Si	D-B	D-Fe	T-Fe
November-February													
N.	3	4	3	4	4	4	4	0	4	4	4	2	1
Min	0.04	0.0	0.0	0.0	0.01	<.01	0.0	--	0.3	7.6	0.9	0.02	--
Max	0.69	0.63	0.57	0.06	0.06	0.09	0.01	--	0.6	21.	1.2	0.09	--
Mean	0.44	0.35	0.38	0.03	0.04	0.04	<.01	--	0.4	12.6	1.0	0.055	--
Med	0.59	0.39	0.56	<.02	0.05	0.04	<.01	--	0.4	11.0	1.0	0.055	0.24
March-May (low flows)													
N.	3	3	3	3	3	3	3	0	3	3	3	3	0
Min	0.46	0.45	0.44	0.01	0.0	0.0	0.0	--	0.3	6.2	0.8	0.09	--
Max	0.62	0.61	0.60	0.01	0.08	0.03	0.04	--	0.5	12.	1.1	0.09	--
Mean	0.54	0.51	0.50	0.01	0.03	0.01	0.02	--	0.4	8.2	0.9	0.09	--
Med	0.53	0.46	0.45	0.01	0.01	0.01	0.01	--	0.4	6.5	0.8	0.09	--
June-October													
N.	6	6	6	6	7	6	6	0	7	6	6	6	2
Min	0.49	0.43	0.41	0.0	0.0	0.03	0.01	--	0.2	1.7	0.9	0.05	0.20
Max	1.1	1.1	1.1	0.02	0.06	0.11	0.07	--	0.9	14.	1.9	0.20	0.87
Mean	0.84	0.83	0.82	0.01	0.01	0.06	0.02	--	0.5	6.1	1.5	0.11	0.54
Med	0.91	0.90	0.89	0.01	0.0	0.06	0.01	--	0.5	4.7	1.5	0.09	0.54

Historical (Pre-1965) Data

Stat	TN	TK_jN	TON	NH_3N	NO_xN	TP	OP	COD	F	Si	D-B	D-Fe	T-Fe
November-February													
N.	0	0	0	0	2	0	0	0	0	2	0	1	0
Min	--	--	--	--	0.07	--	--	--	--	11.	--	--	--
Max	--	--	--	--	0.11	--	--	--	--	14.	--	--	--
Mean	--	--	--	--	0.09	--	--	--	--	12.5	--	--	--
Med	--	--	--	--	0.09	--	--	--	--	12.5	--	0.05	--
March-May (low flows)													
N.	0	0	0	0	1	0	0	0	0	1	0	1	0
Min	--	--	--	--	--	--	--	--	--	--	--	--	--
Max	--	--	--	--	--	--	--	--	--	--	--	--	--
Mean	--	--	--	--	--	--	--	--	--	--	--	--	--
Med	--	--	--	--	<.01	--	--	--	--	9.5	--	0.06	--
March-May (high flows)													
N.	0	0	0	0	3	0	0	0	1	3	0	1	0
Min	--	--	--	--	0.09	--	--	--	--	9.0	--	--	--
Max	--	--	--	--	0.32	--	--	--	--	17.	--	--	--
Mean	--	--	--	--	0.17	--	--	--	--	13.0	--	--	--
Med	--	--	--	--	0.09	--	--	--	0.2	13.	--	0.18	--
June-October													
N.	0	0	0	0	7	1	1	0	4	7	1	4	0
Min	--	--	--	--	<.01	--	--	--	0.3	1.2	--	0.0	--
Max	--	--	--	--	0.09	--	--	--	0.4	8.1	--	0.17	--
Mean	--	--	--	--	<.05	--	--	--	0.3	5.1	--	0.07	--
Med	--	--	--	--	<.01	0.0	0.0	--	0.3	5.2	0.4	0.05	--

Table 38. Summary of chemical analyses of water collected from the Middle Fork Poplar River at the international boundary (combined recent and historical data)--metals and miscellaneous constituents.

Stat	D-Al	T-Al	D-As	T-As	T-B	D-Be	T-Be
N.	4	2	5	2	2	4	1
Min	0.0	0.09	<.0005	<.001	0.84	0.0	--
Max	0.01	0.30	0.003	<.025	1.50	0.0	--
Mean	0.003	0.195	0.001	<.013	1.17	0.0	--
Med	0.0	0.195	0.001	<.013	1.17	0.0	<.005

Stat	D-Cd	T-Cd	D-Cr	D-Cu	T-Cu	D-Hg	D-Li
N.	4	2	4	4	3	4	4
Min	0.0	<.001	0.0	0.0	<.001	0.0	0.08
Max	0.001	<.002	0.0	0.002	0.004	0.0008	0.10
Mean	0.0005	<.002	0.0	0.0005	<.008	0.0002	0.095
Med	0.0005	<.002	0.0	0.0	<.01	0.0	0.10

Stat	D-Mn	T-Mn	D-Mo	D-Ni	D-Pb	T-Pb	D-Se	T-Se
N.	5	2	4	4	4	1	5	1
Min	0.0	0.03	0.0	0.001	0.0	--	0.0	--
Max	0.05	0.14	0.002	0.004	0.002	--	<.0005	--
Mean	0.024	0.085	0.001	0.002	0.0013	--	<.0001	--
Med	0.02	0.085	0.001	0.0015	0.0015	<.004	0.0	<.01

Stat	D-V	T-V	D-Zn	T-Zn	TOC	Phenols	Chl (ug/l)
N.	4	1	4	3	1	1	1
Min	0.0	--	0.01	<.005	--	--	--
Max	0.0043	--	0.02	<.01	--	--	--
Mean	0.0023	--	0.015	<.007	--	--	--
Med	0.0023	<.001	0.015	<.005	8	0.001	<1

Poplar, also demonstrated relatively low turbidity-suspended sediment and color levels, and as a result, the Middle Fork was also indicative of a good to excellent class of fishery on this basis (Table 16) with a general absence of aesthetic degradation due to water colorations. (IV) The concentrations of DO and the %Sat levels were largely similar in the two rivers, except possibly for the winter season, and in both cases, the relatively low coliform concentrations and high DO-%Sat values were indicative of a lack of marked organic and municipal pollution originating within the two drainages. Only a few samples from the two waters exceeded the grab sample criteria for fecal coliforms established by the State of Montana (44).

Additional points of similarity between the two streams in relation to the "field" parameters revolve around salinity and flow. In the first case, (V) DS-SC levels were generally equivalent in the two rivers with samples from each of the streams typically non-saline. The average difference in these variables between the East (E) and Middle (M) Forks, as calculated from (M--DS or SC - E--DS or SC)/(M--DS or SC) values, was found to equal only -5%. The East Fork was apparently more saline than the Middle Fork during the winter and spring but with the Middle Fork slightly more saline during the summer season. Although the current levels of salinity in both rivers appear to be marginal in relation to a "generally excellent" class of fishery, they are suggestive of this type of fishery at the present time; however, only slight increases of salt concentrations would be necessary in both instances to significantly degrade this fishery designation to some lower classification (Table 16).

With respect to flow, (VI) both the Middle and the East Forks of the Poplar River appear to be relatively small streams and the IB on the basis of discharge, and this fact could, of itself, negate the development of a resident fishery. The two rivers are apparently closely equivalent in terms of size with similar average annual discharges equalling 12,961 AF and 12,475 AF respectively (55). This feature, in turn, coincides with the general similarities of their effective Canadian drainage areas. The seasonal differences in flow between the two streams will be considered later in this report.

Several water quality similarities between the East Poplar River and the Middle Fork samples were also observed with respect to the common constituents at the IB (Tables 19 and 36) and also in relation to the nutrient species and some of the other components listed in Tables 20 and 37. For the common ions, these can be briefly summarized as follows: (VII) Both of the streams are best described as having a sodium bicarbonate-type of water that was quite alkaline and very hard in nature. (VIII) For the most part, concentrations of the dissolved, common constituents were generally similar between the streams, and this would include sodium (the dominant cation), calcium-magnesium (the secondary cations in roughly equal amounts) plus total hardness, bicarbonate (the dominant anion) plus total alkalinity, sulfate (the secondary anion) and chloride, fluoride, and potassium (insignificant constituents). In addition, occasionally high and low carbonate and carbon dioxide concentrations were also obtained from the Middle Fork in accord with the high or low pH values of some of the samples. However, levels of bicarbonate-carbon dioxide appear to have been slightly higher in the East Poplar with slightly higher chloride and carbonate values in the other stream. Nevertheless, the general similarities in ionic composition between streams are further illustrated in Table 25 by the fairly close equivalencies of the various ionic concentration ratios between the two IB stations. (IX) In association with the similar total hardness and

sodium concentrations, SAR and %Na values were also nearly equivalent in the two rivers.

Like the East Poplar River, (X) silica concentrations in the Middle Fork were typically below the national average for surface waters (83). Both of the streams demonstrated a decline in this parameter from the winter to the summer season, possibly in association with an enhanced diatom incorporation that occurs during the warmer weather of the latter period, but this seasonal decline in silica was less pronounced in the Middle Fork than in its sister river. In addition, (XI) the various nitrogen species in both of the streams were not at adequate levels to be suggestive of pollutive inputs, and in both cases, (XII) similar and insignificant orthophosphate concentrations were shown in the samples.

As additional points of comparison, concentrations of the trace elements and metals were, in a large percentage of the cases, either generally similar in the East and Middle Forks of the Poplar River at the United States-Canadian border, or they were somewhat lower in the second stream (Tables 22 and 38). This observation also applies to the phenols and to TOC, and to iron and dissolved boron as summarized in Tables 20 and 37. Both the concentrations of dissolved boron and TR-boron were obviously lower in the Middle Fork than in the East Poplar as evidenced by the appropriate tabular comparisons. This was also the case for dissolved iron where 95% of the Middle Fork samples had D-Fe levels less than this metal's reference criteria with none of the samples having D-Fe in excess of its hazardous concentrations (Table 15); these percentages stand in contrast to those obtained from the East Poplar-IB at 88% and 6% respectively. In contrast to the East Poplar, therefore, iron is not suggestive of a biotic problem in the Middle Fork at the present time. This conclusion also applies to most of the other metals, with the possible exception of mercury, since their dissolved and TR concentrations were typically below the corresponding reference criteria. In addition, boron concentrations in both streams were well below the critical levels determined by Wurtz (1945) as necessary in order to afford adverse effects on the aquatic biota, although boron concentrations may have been at adequate levels in the East and Middle Forks to degrade other water uses such as irrigation. As a result, since the phenols and TOC were probably derived from natural sources while being unsuggestive of pollutive and water quality problems, mercury appears to be the only trace element indicative of biotic degradations in the upper segment of the Middle Fork; that is, both the grab sample and average criteria of mercury were exceeded by the Middle Fork-IB collections. This feature was also observed in the East Poplar River.

Other major quality differences between the two forks, in addition to those briefly described above, reside in their winter DO-%Sat levels and in the streams' nutrient status. Although a slight winter depression in DO was also observed in the Middle Fork at the IB, its seasonal decline (Table 35) was much less pronounced than that of the East Poplar (Table 17); as a result, this parameter would not be expected to pose as severe of a stress on the Middle Fork's fishery during the winter as would be the case for the East Poplar River. In addition, the nutrients, including TP, were lower in the Middle Fork than in the more eastern branch of the river suggestive of a reduced eutrophic stress in the first case. This nutrient difference between streams was most distinct in relation to nitrogen where all of the nitrogen species, including the combined forms, were at lower concentrations in the Middle Fork

than in the East Poplar River. These inter-stream nitrogen discrepancies were quite pronounced with respect to ammonia in all seasons with the mean and median concentrations of this variable on the order of 90% to 98% lower in the middle tributary than in the eastern branch. Thus, ammonia toxicity should not pose a water quality problem to the Middle Fork as it does to the East Poplar, and the middle segment, in contrast to the eastern stream, is obviously non-eutrophic as a result of its extremely low NH_3-NO_XN and low TIN levels. This latter feature would indicate that the upper Middle Fork is probably less productive than the eastern tributary of the Poplar, and this in turn is reflected by the comparatively low chlorophyll concentrations of the central stream (Table 38). Like the East Poplar, the Middle Fork is apparently more N-limited than P-limited, but for the central fork, this nitrogen limitation is probably in vogue throughout the year, including the winter season.

Historical water quality data.

Several of the water quality parameters in the Middle Fork demonstrated generally similar concentrations between the post-1970 and the pre-1965 sets of data. These parameters would include pH, turbidity-suspended sediment, and possibly temperature (Table 35), along with NO_XN, fluoride, silica, and D-Fe (Table 37). In view of the lower DS-SC levels in the pre-1965 over the post-1970 quality collections, as described previously, the concentrations of carbonate, calcium, magnesium, total hardness, and potassium (Table 36) were also surprisingly similar between the two data summaries. However, in addition to the fact that the pre-1965 samples appeared to be more colored than the single analysis obtained subsequent to 1970, several of the remaining common constituents did demonstrate a lower historical concentration which is in accord with the higher levels of DS-SC obtained from the more recent collections. These types of variables would include carbon dioxide, bicarbonate, chloride, sulfate, and sodium; in addition, lower values of SAR and %Na were also associated with the pre-1965 data than with the post-1970 set. As a result, the pre-1965 Middle Fork is best described as having a sodium-calcium-magnesium bicarbonate-type of water with a somewhat better quality than the sodium bicarbonate-type of water characterizing the more current stream.

These common constituent and DS-SC differences between the two sets of Middle Fork data might point to the occurrence of water quality degradations in the Poplar River Basin through the past several years. However, such quality differences might also have been due to the somewhat higher flows that were obtained in conjunction with the earlier collections than was the case for the samples taken since 1970, as indicated in Table 35. This possibility is in accord with the observation made on Girard Creek wherein DS-SC levels (Table 32) and common constituent concentrations (Table 33) were higher in the 1973, low water year samples than in the 1974 samples collected during a period of greater overall flow. Reviewing the historical flow data for the Middle Fork station (55), the estimated yearly discharge in the stream at the time that the pre-1965 samples were collected approached 44,000 AF (the highest recorded for the stream), whereas the yearly discharges associated with the later collections were generally much lower than this high value, i.e., less than 28,000 AF. These flow discrepancies between sampling periods, therefore, indicate that the available water quality data are unsuitable and inadequate for use as judgemental criteria with which to document the actual occurrence of historical quality degradations in the Middle Fork drainage. It would appear highly probable that these flow differences per se could account for the quality differences

that became evident between the pre-1965 and post-1970 eras. In any event, the entire upper Poplar Basin, like the Middle Fork, apparently demonstrates an overall better quality of water under the higher flow regimes, although suspended sediment-turbidity, color, organic materials, and nitrogen-phosphorus tend to detract from the better qualities that are established at these times.

Middle Fork Poplar River near Scobey

Field parameters and dissolved solids.

Several of the parametric concentrational and seasonal-change similarities that were observed between the Middle and East Forks of the Poplar River at the international boundary were generally carried downstream to the Scobey locations. In the case of the "field" parameters, as summarized in Table 39 for the Middle Fork-Scobey station, these general similarities would consist of all those previously designated by roman numerals (I to VI) for the upper sites, including the temperature features (I), pH characteristics (II), and the turbidity-suspended levels of the streams (III). Also included would be the streams' coliform-DO status which indicates an absense of organic-municipal pollution (IV). In addition, both of the rivers had similar mean and median DS-SC levels at the lower stations (V), differing by an average of about -10% (except for the summer high flow phase), with slight downstream increases in these variables in both instances. Both the Middle and the East Forks would be classified as typically slightly saline (S8) during the low flow periods while being largely non-saline during the March-May and high flow periods because of the inverse relationship between DS-SC and seasonal flow.

As a final point, number VI, stream discharge increased downstream in both rivers by closely equivalent factors, i.e., 1.54-times in the East Poplar for an average water year versus a value of 1.65-times for the Middle Fork, with generally similar discharges developing at the two Scobey locations (55). However, the flows associated with the grab sample collections were greater in the lower Middle Fork than in the lower East Poplar, comparing Tables 23 and 39, and this latter feature in turn corresponds to the historical discharge information wherein slightly higher annual flows were projected for the Middle Fork near Scobey (21,383 AF) than for the lower segment of more eastern tributary (19,175 AF) (55). Like the East Poplar River, a major proportion of the annual downstream increase in flow in the Middle Fork occurred during the higher discharge months of the March to May period (about 86%), and as a result, the lower reach of this fork also appears to be a relatively small stream for a major part of its annual cycle with average flows well under 5 cfs for seven months of the year.

The percentage of days having flows fitting into one of the six seasonal-discharge classifications defined previously was also calculated for the Middle Fork-Scobey site for water years 1964 to 1975 (72, 94). These percentages were found to be quite similar to those obtained for the East Poplar River as follows: November to February--32.9%, March to May (low flows)--15.4%, March to May (high flows)--6.5%, March to May (extreme high flows)--3.2%, June to October (low flows)--40.7%, and June to October (high flows)--1.2%. The Middle Fork demonstrated a slightly higher frequency of high flow days than the East Poplar, although about 59% of the days with records through this twelve-year span, generally excluding the winter months, had flows in the Middle Fork less than or equal to 5 cfs; of the warm weather days, 81% had flows below this value.

Table 39. Summary of chemical analyses of water collected from the Middle Fork Poplar River near Scobey (lower reach)--field parameters and dissolved solids.

Stat	Flow	Temp	pH	Clr	Turb	TSS	SC	DS	DO	%Sat	BOD	TC	FC
November-February													
N.	6	6	4	0	4	0	6	6	4	4	0	1	1
Min	3.0	0.0	7.7	--	10.	--	1396	918	8.0	60	--	--	--
Max	8.0	2.0	8.5	--	20.	--	1900	1300	11.8	93	--	--	--
Mean	5.68	0.4	7.95	--	16.3	--	1667	1120	9.7	74	--	--	--
Med	6.0	0.0	7.8	--	17.5	--	1700	1130	9.5	71	--	65	10
March-May (low flows)													
N.	5	6	4	0	4	1	6	6	3	3	0	2	3
Min	8.1	0.5	8.2	--	10.	--	665E	459	8.0	83	--	6	3
Max	16.	21.0	8.5	--	40.	--	1320	1104	12.2	98	--	34	73
Mean	13.0	11.3	8.36	--	20.5	--	1071	737	9.6	91	--	20	40
Med	13.	17.8	8.36	--	16.	29.3	1115	701	8.6	93	--	20	44
March-May (high flows)													
N.	4	4	3	0	0	2	4	4	2	0	0	0	0
Min	29	0.0	7.76	--	--	16.	622	537	7.6	--	--	--	--
Max	50E	16.0	8.1	--	--	18.	1100	630	8.5	--	--	--	--
Mean	40E	9.6	7.92	--	--	17.0	848	580	8.1	--	--	--	--
Med	40E	11.3	7.9	--	--	17.	836	577	8.1	--	--	--	--
March-May (extreme high flows)													
N.													
Min													
Max						NO AVAILABLE DATA							
Mean													
Med													
June-October (low flows)													
N.	9	14	12	0	6	7	14	14	12	5	1	1	1
Min	1.5E	5.5	8.3	--	18.	24.	885	575	5.4	75	--	--	--
Max	5.9	26.0	9.8	--	80.	76.	1700	1130	10.6	99	--	--	--
Mean	3.2	19.0	8.86	--	43.0	42.1	1461	957	7.5	89	--	--	--
Med	2.4	21.0	8.9	--	37.5	36.	1495	1007	7.4	85	2.7	250	0
June-October (high flows)													
N.	2	2	2	0	2	1	2	2	1	1	0	0	0
Min	24.E	23.5	8.1	--	36	--	392	234	--	--	--	--	--
Max	127.	25.0	8.56	--	450	--	1173	1012	--	--	--	--	--
Mean	75.5	24.3	8.33	--	243	--	783	623	--	--	--	--	--
Med	75.5	24.3	8.33	--	243	52	783	623	5.0	65	--	--	--

Using the above percentages, the yearly, time weighted mean and median values for turbidity and suspended sediment and for DS and SC were calculated for the lower Middle Fork for comparison to the reference criteria in Table 16, as has been done previously for the East Poplar River. For the Middle Fork near Scobey station, these weighted statistics can be summarized as follows:

	Turbidity	Suspended Sediment	Dissolved Solids	Specific Conductance
Mean	30 JTU	40 mg/l	935 mg/l	1400 umhos
Median	27 JTU	36 mg/l	950 mg/l	1430 umhos

On this basis, turbidity and suspended sediment levels appear to have been slightly higher in the lower Middle Fork than in the East Poplar with a small downstream increase in these constituents in the first stream. However, these types of data were not particularly abundant for either of the two rivers. If the data that are available for the Middle Fork are fairly representative of the turbidity-suspended sediment levels that might be typically obtained from the stream, then the Middle Fork can be graded as having a "good to moderate" class of fishery in relation to these variables; a somewhat higher rating has been assigned to the East Poplar River. Similar to the East Poplar, neither the runoff concentrations of suspended sediment nor its maximum concentrations would appear to be of sufficient magnitude or duration in the Middle Fork to significantly detract from this fork's good to moderate fishery designation. About a three- to five-fold overall increase in these variables would be required to degrade the Middle Fork's fishery to that of a "poor" classification with reference to the suspended materials in the stream.

In contrast to suspended sediment, the weighted mean and median DS-SC levels in the Middle Fork near Scobey were somewhat less than those calculated for the lower East Poplar, as intimated previously, but the two streams were again generally similar in this regard since they differed by only an average value of -11%. On the basis of dissolved materials, the lower Middle Fork should provide a "good" class of fishery that appears to be intermediate in quality to the type of fishery now obtained from the upper and lower reaches of the East Poplar, assuming no other limiting factors. The degradation of the Middle Fork fishery to a "poor" designation would probably require at least a three-fold increase of salinity over the levels that presently characterize the stream.

With general similarities of flows and DS concentrations between the Middle and East Forks of the Poplar River, the Middle Fork will apparently have a reduced dilution capacity relative to the Poplar mainstem in the event the East Poplar should eventually experience some water quality degradations, such as increased salinities, subsequent to the operation of the Coronach generating facilities. That is, the Middle Fork will not be as effective in ameliorating such impacts as would be the case if the conjoining stream had happened to have higher flows and/or lower DS levels than what has been actually observed to occur in the drainage. For example, if the Coronach development should produce a two-fold increase in East Poplar salinities during the warm weather season with a 50% reduction in flow, such as during the month of August in an average water year, the Middle Fork will only alter these impacts in the upper main Poplar near Scobey to a 1.54-fold increase in salinity with a 35% reduction in average flows at this particular location on the mainstem. As a result, although the Middle Fork will not be directly affected by the Coronach

development, the future fate of this stream may still have an effect on the way the lower portions of the Poplar drainage respond to these facilities since any diversions of water from this tributary, or any acts that tend to increase the Middle Fork's salinity levels, will further reduce the already weakened potential of this river to dilute the impacts that are carried downstream from Canada via the East Poplar River. That is, if Middle Fork flows are reduced by 25% in August with a 25% increase in the stream's salinity levels, then the fork's dilution capacity would be further retarded in the face of the East Poplar impacts delineated previously, affording in this case a 43% reduction in mainstem flows and a 1.71-fold increase in mainstem salinity levels immediately below the confluence of the two tributaries. Thus, careful consideration should be given to these types of factors before waters are randomly transferred between the Poplar sub-basins to supplement developmental uses in any particular area.

As described above, the lower Middle Fork of the Poplar drainage should possess a fairly good type of fishery on the basis of its dissolved and suspended materials concentrations with suspended sediment possibly representive of the more limiting factor of the two variables in this particular instance. The DO characteristics of the stream (Table 39) were in accord with this relatively high fishery designation in being at levels that are largely non-limiting to most fish populations. Like the upper Middle Fork, a part of this non-limitation in the lower reach was due to an absense of the severe winter depressions in DO levels that have been noted for the East Poplar River. A slight depression of this kind did become evident in terms of the %Sat data, but none of the winter samples demonstrated DO concentrations below the minimum levels specified in Montana's Water Quality Standards for $B\text{-}D_3$ streams (44). A few of the samples collected through the year did have DO's below the Montana requirement for a cold water fishery, and this indicates that the Middle Fork is probably most suggestive of a warm water stream. But in no cases were the low levels of DO (3 mg/l) specified as lethal to many sport fish approached in any of the Middle Fork samples (59), including those that were collected during the critical winter season.

As observed for oxygen, the temperature and pH readings of samples from the lower Middle Fork were also indicative of either a warm water, $B\text{-}D_3$ stream or possibly a marginal, $B\text{-}D_2$ water. In the first case, the mean and median values of pH during the summer season were well above that level typically suggestive of a cold water fishery (Table 7), and although the minimum values of pH from the samples were noncritical, a few extremely high pH's were obtained from the river on occasion that were above the maximum recommended for a good fishing water (88); however, these high pH samples were relatively scarce. Similar to this pH factor, grab sample temperatures taken during the summer season were also typically above those levels that characterize a superior cold water stream. This feature is further illustrated in Table 40 wherein about 50% of the June to October temperature readings were in excess of the 19.4C reference value. As indicated in Table 40, median temperatures taken in conjunction with the grab samples were somewhat higher than those obtained with a continuous recorder, and a warm weather median calculated in the latter instance would appear to be below the cold water reference criteria; but this factor is only suggestive of a marginal cold water stream in view of the much higher maximum values that were obtained from the stream. The fact that several of the temperature readings from the lower Middle Fork were in excess of the juvenile tolerance limits for several cold water species, such as rainbow (78), brown

Table 40. Temperature characteristics of the lower Middle Fork Poplar River near Scobey expressed as the percentage of readings falling within various temperature ranges specified for cold water (19.4C) and warm water (26.7C) fisheries; minimum, maximum, and median values are also listed. Data were taken from (1) Aagaard (1969) and other sources and from (2) unpublished records collected by the Montana Department of Fish and Game (Needham, 1977).

Period of Observations	Temperature Range or Statistic	Winter November-February	Runoff March-May	Warm Weather June-October
Grab sample temperatures (1): March, 1949 to July, 1977	<19.4C	100%	96%	40%
	19.4C to 26.7C	0%	4%	58%
	>26.7C	0%	0%	2%
	Minimum	0.0C	0.0C	5.5C
	Maximum	4.4C	22.2C	27.7C
	Median	0.3C	2.2C	21.0C
	Sample Number	12	78	52
Continuous daily records (2): April, 1976 to November, 1977				
Maximum temperatures	<19.4C	100%	77%	50%
	19.4C to 26.7C	0%	23%	49%
	>26.7C	0%	0%	1%
	Minimum	0.6C	4.4C	0.6C
	Maximum	6.1C	22.8C	28.3C
	Median	3.9C	16.1C	19.4C
	Sample Number	20*	111**	297
Minimum temperatures	<19.4C	100%	100%	86%
	19.4C to 26.7C	0%	0%	14%
	>26.7C	0%	0%	0%
	Minimum	0.0C	1.1C	0.0C
	Maximum	4.4C	18.3C	22.8C
	Median	1.7C	11.1C	15.6C
	Sample Number	21*	110**	286

*Month of November only. **Excludes the month of March.

(82), and brook (84) trout, would indicate that this stream was definitely more warm water than cold water in character. In contrast, none of the summer temperatures from the river exceeded the tolerance limits for various warm water species, e.g., northern pike (92), channel catfish (79), and fathead minnow (85), and only a small percentage of the readings (Table 40) were greater than the maximum temperatures suggested for a warm water stream (44). On the basis of the "field" parameters, therefore, the Middle Fork would most likely have a fairly good, warm water fishery, but this assumes the non-occurrence of other limiting factors such as inadequate water volumes and chemical toxicities, as might develop from high ammonia concentrations or from extremely low flows.

Common constituents.

Similar to the other stations in the Poplar River drainage, the various common constituents in samples from the lower Middle Fork were probably at inadequate concentrations to individually affect the aquatic biota of the stream (Table 41). On a cumulative basis, however, they did provide for only a marginally excellent class of fishery in the lower reach by contributing to the stream's total salinity levels and osmotic stress characteristics. Bicarbonate, sulfate, and sodium were particularly notable in this regard because of their comparatively high concentrations, accounting for over 87% of the stream's median dissolved solids levels. The concentrations of such common constituents, as listed in Table 41 for the lower Middle Fork, were generally similar on a seasonal basis to those obtained from the East Poplar near Scobey (Table 24), and the ionic composition similarities between the upper reaches of the two rivers, as has been described previously and designated by roman numerals VII, VIII, and IX, were generally carried downstream to the two lower sampling stations. The major exception was found in the summer high flow period when the East Poplar River at both sites had unexpectedly high DS-SC levels relative to its flow and much higher dissolved ion concentrations at this time than the Middle Fork at either its border or Scobey locations. Apart from this summer high flow period, the ionic composition similarities between the two streams would include the two forks' very hard, highly alkaline, and sodium bicarbonate natures (VII), the same dominant, secondary, and insignificant cations and anions (including fluoride, Table 42) (VIII), and their similar SAR and %Na values (IX). The only distinctive ionic difference between the two streams' lower reaches was found in the higher sulfate concentrations of the East Poplar over the middle river, and this feature is also reflected in the higher HCO_3/SO_4 ratios of the lower Middle Fork as listed in Table 25. For the most part, however, the ionic concentration ratios in Table 25 further illustrate the chemical similarities of the two streams, which might be expected in relation to the contiguous nature of their drainage areas.

As indicated in Table 25, the Middle Fork Poplar River, like the East Poplar, became more sodium sulfate in character in a downstream direction from the United States-Canadian border, except for the spring season, with a decrease in the stream's HCO_3/SO_4 ratios and an increase in its $Na/(Ca + Mg)$ factors in going from the IB to Scobey. At the Scobey station, the Middle Fork had a slightly more distinct sodium bicarbonate composition than the East Poplar at this location with Middle Fork having typically higher values for these two ratios than its sister stream. In addition, the Middle Fork had a greater predominance of calcium over magnesium than the East Fork with the higher Ca/Mg ratios in the first stream typically greater than one. But the Middle Fork

Table 41. Summary of chemical analyses of water collected from the Middle Fork Poplar River near Scobey (lower reach)--common constituents.

Stat	CO_2	HCO_3	CO_3	TA	PA	Cl	SO_4	Ca	Mg	TH	Na	SAR	%Na	K
November-February														
N.	4	6	4	6	0	6	6	6	6	6	6	6	6	6
Min	3.5	613	0.0	503	--	11.	260	34.	37.	240	230	5.5	59.	6.9
Max	30.	954	15.	782	--	19.	350	69.	58.	410	340	8.2	72.	9.1
Mean	18.6	797	3.8	658	--	14.0	303	51.8	48.0	328	288	7.0	65.0	8.2
Med	15.5	800	0.0	657	--	13.5	305	53.	49.	345	300	6.9	65.	8.3
March-May (low flows)														
N.	3	6	4	6	0	6	6	6	6	6	6	6	5	5
Min	2.9	367	0.0	301	--	4.3	94	34.4	23.	190	94	3.0	50.	5.8
Max	4.2	655	10.	554	--	9.1	210	48.	48.9	310	202	5.2	59.	11.
Mean	3.4	519	4.8	431	--	6.6	161	39.7	38.2	256	163	4.4	55.8	7.5
Med	3.0	500	4.5	435	--	6.3	160	39.	39.	264	170	4.7	57.	6.4
March-May (high flows)														
N.	0	2	1	2	0	2	2	2	2	2	4	2	1	2
Min	--	306	--	251	--	4.8	78	29.0	13.2	127	44	3.0	--	8.4
Max	--	470	--	386	--	5.0	100	48.	34.	260	114	3.7	--	9.2
Mean	--	388	--	319	--	4.9	89	38.5	23.6	194	91	3.4	--	8.8
Med	--	388	0.0	319	--	4.9	89	38.5	23.6	194	103	3.4	47	8.8
March-May (extreme high flows)														
N.														
Min														
Max						NO AVAILABLE DATA								
Mean														
Med														
June-October (low flows)														
N.	5	7	5	8	0	8	8	14	14	7	14	7	7	7
Min	1.3	440	0.0	360	--	4.9	140	23.6	27.	190	140	4.5	61.	7.9
Max	3.8	728	47	628	--	12.	330	46.	53.8	290	320	8.6	73.	10.
Mean	3.0	608	25	541	--	10.5	259	31.2	41.1	247	268	7.0	67.4	9.4
Med	3.4	615	28	554	--	11.	281	30.4	42.3	250	274	7.0	69.	9.7
June-October (high flows)														
N.	1	2	2	2	0	2	2	2	2	2	2	2	1	2
Min	--	198	0.0	162	--	2.2	40	26.	12.	110	38	1.5	--	8.2
Max	--	571	17.	496	--	6.8	150	32.2	38.8	240	188	5.3	--	8.3
Mean	--	385	8.5	329	--	4.5	95	29.1	25.4	175	113	3.4	--	8.3
Med	2.5	385	8.5	329	--	4.5	95	29.1	25.4	175	113	3.4	40	8.3

Table 42. Summary of chemical analyses of water collected from the Middle Fork Poplar River near Scobey (lower reach)--nutrients and other constituents.

Stat	TN	TK_jN	TON	NH_3N	NO_xN	TP	OP	COD	F	Si	D-B	D-Fe	T-Fe
November-February													
N.	4	4	4	4	6	4	6	0	6	6	6	6	0
Min	0.03	0.02	0.02	0.0	0.0	0.04	0.0	--	0.5	3.1	1.3	0.02	--
Max	0.92	0.84	0.51	0.33	0.12	0.32	0.25	--	1.0	17.	1.8	0.10	--
Mean	0.50	0.42	0.28	0.15	0.07	0.12	0.05	--	0.7	9.1	1.6	0.05	--
Med	0.53	0.42	0.24	0.13	0.09	0.05	0.0	--	0.6	7.7	1.6	0.03	--
March-May (low flows)													
N.	3	3	3	4	5	4	6	0	6	5	5	5	1
Min	0.52	0.44	0.43	<.01	<.01	0.01	0.0	--	0.3	5.9	0.5	0.01	--
Max	0.82	0.81	0.80	0.04	0.36	0.05	0.03	--	0.6	10.	1.1	0.21	--
Mean	0.62	0.59	0.57	0.02	0.09	0.03	0.01	--	0.5	7.4	0.8	0.09	--
Med	0.53	0.53	0.49	0.01	0.01	0.03	0.0	--	0.5	6.7	0.8	0.06	0.70
March-May (high flows)													
N.	0	0	0	1	2	1	2	0	2	1	1	1	1
Min	--	--	--	--	0.0	--	0.0	--	0.3	--	--	--	--
Max	--	--	--	--	0.51	--	0.02	--	0.3	--	--	--	--
Mean	--	--	--	--	0.26	--	0.01	--	0.3	--	--	--	--
Med	--	--	--	0.28	0.26	0.13	0.01	--	0.3	8.3	0.6	0.11	<.01
March-May (extreme high flows)													
N.													
Min													
Max					NO AVAILABLE DATA								
Mean													
Med													
June-October (low flows)													
N.	5	6	5	6	8	6	7	0	7	7	7	7	7
Min	1.2	0.75	0.96	<.01	0.0	0.03	0.0	--	0.4	1.3	0.9	0.02	0.63
Max	1.8	1.8	1.8	0.2	0.17	0.18	0.02	--	0.7	11.	1.8	0.05	2.6
Mean	1.34	1.21	1.25	0.09	0.03	0.12	0.01	--	0.5	6.9	1.5	0.04	1.23
Med	1.2	1.2	1.2	0.09	0.02	0.13	0.01	--	0.5	6.1	1.6	0.03	1.1
June-October (high flows)													
N.	1	2	1	2	2	2	2	0	2	1	1	1	1
Min	--	0.61	--	0.03	0.02	0.06	0.02	--	0.2	--	--	--	--
Max	--	3.0	--	0.07	0.27	0.19	0.08	--	0.5	--	--	--	--
Mean	--	1.81	--	0.05	0.145	0.13	0.05	--	0.3	--	--	--	--
Med	3.3	1.81	3.0	0.05	0.145	0.13	0.05	--	0.3	8.8	0.4	0.03	1.2

also demonstrated a significant drop in its Ca/Mg ratio during the low flow, warm weather season possibly as a result of the biogenetic precipitation of calcium during this biologically active period, as has been noted for the eastern tributary. Similar to the East Poplar River, the Middle Poplar had a sodium bicarbonate composition throughout the year, although the river was more sodium sulfate in nature during the low flow periods than during the runoff stages with lower and higher HCO_3/SO_4 and Na/(Ca + Mg) ratios, respectively, in the first instance; in turn, the first ratio increased while the second ratio declined upon the advent of runoff conditions, both in the spring and the summer, pointing to the inputs of a more calcium bicarbonate type of water at these times. As indicated in Table 25, Ca/Mg ratios also showed a marked increase in the Middle Fork with the onset of higher flows. These ratios point to the occurrence of two kinds of waters entering the middle drainage of the upper Poplar--a low flow, baseline input, as from groundwater, that appears to have a noticeably sodium sulfate composition, and a surface water, runoff input that appears to be much more calcium bicarbonate in nature than the baseline flow component. These features also became evident in the East Poplar River.

Nutrients and other constituents.

Another point of difference between the lower Middle and East Forks of the Poplar River resides in the streams' silica concentrations. As indicated in Table 42 and noted for the upper station on the middle river (X), silica levels in the lower Middle Fork were typically below the nation's average (83) while being either generally similar to or slightly lower than the mean value for Montana's streams (8 mg/l) (12). This was also observed for the East Poplar near Scobey (Table 26), but the lower Middle Fork did not demonstrate the distinct winter to summer decline in this constituent that was evident in its upper reach (Table 37) and in the East Poplar drainage. As a result, but with the exception of the winter period, the seasonal concentrations of silica were higher in the lower Middle Fork than in the lower East Poplar, and the silica levels of the first reach were also greater than those obtained from the middle segment's upper station for the March to October period (Table 37). In contrast, boron concentrations were lower in the Middle Fork near Scobey, showing no consistent downstream concentrational changes, than in the East Poplar River, while dissolved iron levels were essentially the same among the lower and upper Middle Fork reaches and the lower segment of the East Poplar. In none of these cases was dissolved iron suggestive of water quality problems, as was observed for the East Poplar-IB location, and in all of these streams, boron concentrations were well below those levels that would implicate toxic effects on the aquatic biota (Wurtz, 1945). This latter conclusion would also apply to silica and to the levels of fluoride that were obtained from the East and Middle Forks of the Poplar drainage (Table 15).

The lower segments of the East and Middle Forks also differed to some extent in terms of their combined nitrogen concentrations with somewhat lower values typically obtained from the second stream (Tables 26 and 42). But no distinct downstream changes in combined nitrogen levels became evident within the middle river, although its ammonia and NO_XN concentrations possibly increased to some degree from the IB to Scobey (Tables 37 and 42). Like the other streams inventoried to this point, total nitrogen (TN), total organic nitrogen (TON), and total Kjeldahl nitrogen (TKjN) concentrations were not at adequate levels in the lower Middle Fork to be suggestive of organic pollution

entering the middle tributary between the IB and Scobey stations (XI). This conclusion might also be derived from the Middle Fork-Scobey's ammonia concentrations and its single TOC assessment (Table 43); this latter analysis provided a concentration that is closely equivalent to those obtained from natural, unpolluted waters (87). Similar to the lower East Poplar, combined nitrogen concentrations were somewhat higher in the Middle Fork during summer season than during the spring or winter, and this may have been a reflection of the greater biological activities of the warm weather period. In turn, as a result of the increased biotic uptake and incorporation of nitrogen nutrients during the high temperature season, ammonia and NO_X levels tended to decline from the winter to the summer, as shown in Table 42.

As observed for the upper reach of the Middle Fork and for the Scobey segment of the East Poplar, ammonia concentrations at the lower Middle Fork station were relatively low and nondistinctive for a major portion of the year. In spite of the slightly higher ammonia levels under the reducing and biologically dormant conditions of the ice-covered, winter season, total ammonia concentrations would have been only very rarely at adequate levels in the middle river to provide for sufficient quantities of its nonionic form to be indicative of biotic toxicities at the pH levels of the stream. Since the NO_XN concentrations of the lower Middle Fork were also relatively low, the concentrations of TIN in this segment, like those in the upper reach, did not point to the occurrence of eutrophic conditions in the stream. That is, only about 9% of the stream samples had TIN levels above the lower reference criterion for nitrogen eutrophication, and none of the samples exceeded this nutrient's upper reference value. These latter features of the Middle Fork river stand in contrast to the observations on ammonia toxicity and eutrophication that have been made for the upper portion of the East Poplar drainage above Scobey. Thus, several of the water quality problems that apparently characterize the upper segments of the East Poplar River appear to be largely absent from the Middle Fork of the Poplar Basin.

Orthophosphate (OP) levels were again largely negligible in the lower Middle Fork (XII), as has been noted for most of the other streams in the upper Poplar drainage, with 87% of the lower river samples having OP concentrations well below 0.05 mg P/1. But the lower station on the Middle Fork, like the other upper Poplar streams, did demonstrate relatively high phosphorous levels in the combined or TP form (Table 42). As observed for the East Poplar, TP concentrations were comparatively low in the Middle Fork during the cold weather, November to February season with a marked increase in this variable into the summer period. This summer increase in the fork's TP levels was possibly related to the enhanced biotic uptake of the phosphorous nutrient at this time, as well as the nitrogen nutrients, with the greater incorporation of such nutrients into organic linkage occurring during this biologically active, warm weather period. In any event, TP concentrations in the lower segment of the Middle Fork were at adequate levels to be suggestive of eutrophic conditions for a major part of the year; about 65% and 47% of the samples collected from the stream through all of the seasons had TP concentrations in excess of its lower and upper reference criteria, respectively. This potential eutrophy was particularly distinct during the biologically critical summer season when mean and median TP concentrations were well over the upper reference value for the phorphorous nutrient with 75% of the warm weather samples having TP levels in excess of 0.1 mg P/1 (with 88% in excess of 0.05 mg P/1).

Table 43. Summary of chemical analyses of water collected from the Middle Fork Poplar River near Scobey (lower reach)--metals and miscellaneous constituents.

Stat	TOC	D-Al	T-Al	D-As	T-As	T-B	T-Ba	D-Be	T-Be
N.	1	4	8	4	8	9	1	4	1
Min	--	0.0	0.3	0.001	<.001	0.4	--	0.0	--
Max	--	0.02	2.1	0.005	<.025	2.0	--	0.0	--
Mean	--	0.01	1.08	0.0023	<.019	1.3	--	0.0	--
Med	14	0.01	1.0	0.0015	<.025	1.4	0.1	0.0	<.01

Stat	D-Cd	T-Cd	T-Co	D-Cr	T-Cr	D-Cu	T-Cu	D-Hg	T-Hg
N.	4	4	1	4	3	4	10	4	4
Min	0.0	<.001	--	0.0	<.05	0.0	<.002	0.0	<.0002
Max	0.001	0.005	--	0.0	<.05	0.002	0.01	0.0014	<.0002
Mean	0.0003	<.002	--	0.0	<.05	0.001	<.007	0.0004	<.0002
Med	0.0	<.001	<.01	0.0	<.05	0.001	0.006	0.0	<.0002

Stat	D-Li	T-Li	D-Mn	T-Mn	D-Mo	T-Mo	D-Ni	T-Ni
N.	4	1	11	4	4	1	4	1
Min	0.05	--	0.0	0.05	0.001	--	0.002	--
Max	0.13	--	0.07	0.10	0.003	--	0.004	--
Mean	0.085	--	0.018	0.075	0.0018	--	0.0025	--
Med	0.08	0.10	0.01	0.075	0.0015	<.10	0.002	<.01

Stat	D-Pb	T-Pb	D-Se	T-Se	T-Sr	D-V	T-V	D-Zn	T-Zn
N.	4	4	4	9	0	4	2	4	10
Min	0.0	<.005	0.0	<.001	--	0.0	<.1	0.0	<.005
Max	0.003	<.05	0.0	<.01	--	0.004	<.11	0.02	0.04
Mean	0.0015	<.039	0.0	<.007	--	0.0016	<.105	0.01	<.011
Med	0.0015	<.05	0.0	<.01	--	0.0011	<.105	0.01	<.01

In spite of these high phosphorous concentrations, however, the Middle Fork Poplar River is probably best graded as non-eutrophic at the present time because of the river's low TIN concentrations pointed to previously. As a result, this stream, like the East Poplar, is obviously much more nitrogen limited than phosphorous limited throughout the year. Only 6% of the Middle Fork samples would be expected to have both nitrogen and phosphorus in excess of the lower eutrophication reference levels for these nutrients, and none of the samples would have both nutrients at levels greater than the upper criteria utilized by the Environmental Protection Agency in their national water inventory (68). Therefore, in contrast to the case for salinity described earlier, the Middle Fork Poplar River might be fairly effective in diluting any nutrient enrichments that might originate in Canada in association with the Coronach facilities and thereafter carried downstream into Montana via the East Poplar River; but this feature would apply primarily to the nitrogen, i.e., NO_XN and ammonia, rather than the phosphorous nutrients.

Metals and miscellaneous constituents.

As described previously for boron, most of the other metals and trace elements summarized in Table 43 were not at adequate concentrations to afford toxic effects on the Middle Fork's aquatic biota. This would include, most obviously, As, Ba, Be, Cd, Co, Cr, Cu, Mn, Ni, Pb, Se, and Zn with both the dissolved and TR concentrations of these constituents well below the appropriate reference criteria presented in Table 15. Similarly, Li, Mo, and V can also be added to this listing since markedly high levels of these elements, as noted previously for lithium (41), have to be present in order to invoke toxic responses in various aquatic organisms; e.g., between 4.8 to 30 mg/l of vanadium, depending upon the hardness of the water, are required to affect the fathead minnow (93). In addition, Al and Fe, regardless of their relatively high TR concentrations, might also be placed into the non-affecting metals category with respect to the lower reach of the middle Poplar River since their dissolved concentrations were consistently well below the metals' reference values. Of the various trace elements analyzed in samples from the lower station on the middle river, therefore, only mercury affords a possible exception to the above conclusions with its dissolved and thereby its total concentrations on occasion in excess of its grab sample criterion. This is suggestive of a possibility for sporadic mercury problems in the stream, but inadequate data are available with which to judge any violations of its average reference value which would be indicative of a more serious problem at the lower station.

The fact of mercury acting as a potential water quality problem, as judged on the basis of water sample concentrational data and associated reference criteria, appears to be a general case for the upper Poplar drainage and for certain other drainages in Montana such as the Yellowstone River Basin (86). But in most of these cases, insufficient data are now at hand with inadequate detection limits to specifically delineate the actual magnitude of this potential water quality difficulty. Tissue analyses of fish species collected from the Poplar Basin (walleye and northern pike) demonstrated no detectable concentrations of mercury at the sensitivity level of the test, i.e., less than 2 ug of Hg per gram of fish tissue (unpublished data of the State Water Quality Bureau, MDHES). But unfortunately, this detection limit is also unsatisfactory for judging the actuality a mercury problem in the Poplar Basin since artificial exposures of trout to only .0.05 ug/l of methylmercury for a three month period produced tissue concentrations of mercury on the order of 0.5 ug of Hg

per gram of fish (90); this latter value is equal to the Food and Drug Administration recommendation for mercury in the edible portions of fish flesh (24).

The reference levels for mercury put forth by the Environmental Protection Agency for surface waters are distinctively low in relation to the other metals and are given in the TR form (0.2 ug TR Hg/l in grab samples with a 0.05 ug TR Hg/l average value), and the 0.05 ug/l figure is about equal to the supposed average concentration of mercury in natural waters (24). As a result of these factors, the common occurrence of mercury in excess of its reference criteria would not be totally unexpected for a variety of drainage systems. The establishment of such low TR reference levels for mercury in close equivalence with its average concentration in natural waters would appear to be somewhat incongruous, but these reference values were not established without good reason as follows: (1) The types of mercury species and their quantities in natural waters cannot be readily determined because of the possibility of biological transformations between the inorganic and organic phases (24). (2) Mercury can have toxic effects while in various combined forms such as methylmercury, as indicated previously. (3) Aquatic organisms such as trout can significantly concentrate minute environmental quantities of this constituent in their tissues, on the order of 10^4-times (90), providing magnified effects on organisms further up the food chain, e.g., man. And (4) extremely low levels of mercury can be quite toxic to certain aquatic organisms; the 0.1 ug/l level purported to be lethal to northern pike upon prolonged exposure (90) would serve as one example of this toxicity. Thus, with the close similarity between mercury's natural concentration and the levels that can produce toxic effects, it would seem likely that particular streams might have a natural mercury problem without the benefit of any pollutive inputs.

In view of the above discussion and the fact that detectable concentrations of dissolved and TR mercury were obtained in many of the samples from the upper Poplar drainage, including the Middle Fork, this constituent, regardless of its low, overall concentrations, might still be viewed as an actual hazard within this aquatic system at the present time even though the magnitude of this problem cannot be exactly documented until more information becomes available for the streams. The general conclusion developed by the Environmental Protection Agency for this trace element might also serve as a guide for evaluating the future impacts of mercury in the Poplar River Basin relative to the Coronach development; that is, " . . . little mercury can be added to the aquatic environment (24)." Therefore, any enhancement of mercury concentrations in the Poplar streams as a result of the Coronach facilities might be viewed as detrimental in relation to the current mercury status of their waters. This conclusion might also apply to certain of the other trace elements, such as silver, since some of these constituents can also afford toxic effects on aquatic organisms when in relatively minute quantities; however mercury is particularly distinctive in this regard.

West Fork Poplar River at the International Boundary

Field parameters and common constituents.

As indicated in Table 44, water quality data from the West Fork of the Poplar River at its border location were also unclassified on the basis of flow following the seasonal separations. But in contrast to the upper Middle Fork, this lack of a secondary data separation was not related to the small quantities

Table 44. Summary of chemical analyses of water collected from the West Fork Poplar River at the international boundary--field parameters and common constituents.

Stat	Flow	Temp	pH	Clr	Turb	TSS	SC	DS	DO	%Sat	BOD	TC	FC
November-February													
N.	4	7	7	3	7	2	7	7	7	4	0	3	3
Min	0.03	0.0	7.4	30	3.	2.	1226	801	2.2	16	--	7	2
Max	0.50	4.	8.5	50	7.	6.	2635	1939	11.	86	--	200	20
Mean	0.32	1.0	7.89	37	4.7	4.	1824	1270	6.6	43	--	79	11
Med	0.38	0.2	7.7	30	4.7	4.	1810	1250	6.2	34	--	29	11
March-May													
N.	3	5	5	2	5	1	5	5	5	3	0	3	4
Min	0.43	1.0	7.3	10	2.8	--	301	186	6.2	48	--	<10	<1
Max	2.8	16.5	8.5	80	9.	--	1250	809	11.7	107	--	22	23
Mean	1.51	9.1	8.04	45	6.1	--	844	534	9.6	85	--	<16	<10
Med	1.3	10.5	8.2	45	7.	13.	870	551	10.7	99	--	17	<10
June-October													
N.	6	10	10	5	10	4	10	10	8	5	0	2	2
Min	0.1	5.5	7.9	10	1.6	4.	792	501	5.4	56	--	<1	<1
Max	0.55	22.0	9.9	60	30.	25.7	1600	1100	11.	90	--	<10	<10
Mean	0.28	17.0	8.8	34	11.8	10.9	1265	814	7.7	81	--	<6	<6
Med	0.25	20.0	8.8	40	9.6	7.0	1330	858	7.3	86	--	<6	<6

Stat	CO_2	HCO_3	CO_3	TA	PA	Cl	SO_4	Ca	Mg	TH	Na	SAR	%Na	K
November-February														
N.	7	7	7	7	3	7	7	7	7	7	7	4	7	7
Min	4.1	630	0.0	536	0.0	6.4	187	28.	29.	190	225	8.0	68.	10.0
Max	66.	1608	17.	1319	9.5	12.	388	59.	62.	345	600	9.3	78.0	18.
Mean	26.1	1002	4.1	777	3.2	8.0	279	41.6	43.4	283	367	8.8	72.3	12.4
Med	22.	947	0.0	829	0.0	7.7	300	40.	43.	300	340	9.0	72.	11.7
March-May														
N.	5	5	5	5	2	5	5	5	5	5	5	3	5	5
Min	2.0	173	0.0	142	0.0	3.3	15	19.	15.	110	14	5.8	16.5	5.6
Max	15.	610	17.	530	8.9	5.7	180	60.	52.	364	240	8.0	75.	13.4
Mean	6.2	424	6.7	359	4.5	4.2	108	30.8	25.6	182	134	7.0	54.2	8.7
Med	5.1	466	6.	382	4.5	4.	98	26.	19.	137	140	7.2	72.	8.3
June-October														
N.	8	9	9	8	3	9	10	10	10	10	10	6	10	10
Min	0.1	445	0.0	380	0.0	3.0	98	12.	23.	136	87	9.5	35.6	7.4
Max	3.9	720	141.	760	45.	7.4	225	45.	54.	333	360	12.	82.	12.0
Mean	1.6	542	59.2	493	15.	5.0	168	21.6	29.9	180	244	10.4	70.8	9.9
Med	1.1	484	49.	576	0.0	5.1	168	18.	28.5	160	275	10.0	77.	10.3

of parametric numbers, but rather, to an absence of quality sample collections obtained in association with stream flows in excess of 19.9 cfs. This occurrence in turn is related to the extremely small size of the upper West Fork in Montana in comparison to the other forks at their IB stations. The upper West Fork flows gaged in conjunction with the sample collections were consistently below three cfs throughout the year, even during the March to May, high flow period, and the estimated average annual flow of the West Fork at its border station was equal to only 3799 AF which is between 69% and 71% lower than the mean yearly flows measured for the East and Middle Forks in their upper reaches in Montana (55). United States Geological Survey estimates of average monthly flows in the upper West Fork were below one cfs for eight months of the year and below three cfs for ten months, excluding the spring runoff months of March and April, and zero daily flows were estimated for a major part of the winter season (55). Such relatively low flows in the West Fork at the IB coincides with the small portion of its drainage area located above this station in Canada.

The small size of the upper West Fork provides one of the major distinctions between this stream and the other forks of the Poplar River in Montana. In correspondence to this feature, the DS-SC levels of the upper West Fork were also somewhat higher than those in the upper reaches of the east and middle branches in the State. The seasonally weighted mean and median DS-SC levels of the West Fork-IB samples equalled 893 and 910 mg/l and 1343 and 1372 umhos respectively, and these values are between 1.04- and 1.10-times higher than those obtained from the East Poplar River at its border station. Regardless of these slightly higher levels, the weighted means and medians of these variables in the upper West Fork are still suggestive of a "good" (rather than a "generally excellent") class of fishery on the basis of salinity in this particular reach; but these data do point to the marginal nature of salinity in the upper Poplar drainage even though this parameter at its current levels should not affect the West Fork fishery to any significant extent. More importantly, the small size of the stream in its IB segment probably precludes the establishment of a resident sport fishery. However, this reach of the river might be utilized as a spawning grounds for resident fish populations downstream and in the Poplar mainstem, and salinity could have some adverse effects in this regard. Future increases of DS-SC in the upper West Fork on the order of 50% over present levels could degrade its fishery potential to only a "fair" designation.

Like the case for flow and DS-SC, the colored nature of the upper West Fork waters provides another distinguishing feature between this stream and the other branches of the Poplar River, although none of the remaining "field" parameters monitored in the upper West Fork, except possibly for the winter dissolved oxygen levels, were particularly distinctive or at different levels from those observed in the other forks (Table 44). Waters in all of the Poplar branches were somewhat colored during the short-lived, spring runoff period as a result of overland flow bringing in soil-related organic materials such as humic and fulvic acids. But in contrast to the other forks, water coloration was also evident in the West Fork-IB samples during the low flow, June to February period with color at these times also noticeable to the human eye. This would point to some degree of aesthetic degradation. However, neither the values of turbidity-suspended sediment nor the concentrations of coliform organisms were at adequate levels to aesthetically degrade its waters. Total and fecal coliform concentrations were well within the standards specified by the State of Montana for these

biological parameters (44), and these variables were unsuggestive of municipal pollution reaching the stream. In turn, the mean and median levels of turbidity and suspended sediment were generally similar to those obtained from the other forks, and they were indicative of an "excellent" class of fishery in the upper reach on this basis. In addition, the seasonal maximums and spring runoff levels of suspended sediment in the upper West Fork were not at sufficient concentrations to degrade this fishery classification.

Similar to the other Poplar branches, values of pH and temperature in the upper West Fork were relatively low under the reducing, cold weather conditions of the winter season with marked increases in these variables into the summer period. In opposition to pH and temperature, DO levels in the West Fork-IB samples were relatively high during the spring and summer in contrast to the depression of this variable that was obtained in the ice-covered, winter phase; this depression was most distinct in terms of the %Sat values (Table 44). However, these water quality alterations were most likely related to natural biological manifestations rather than to man's activities in the drainage, as has been described previously. Summer DO concentrations and the %Sat levels of the upper West Fork during the warm weather period appeared to be slightly lower than those in the East Poplar, and this feature might have been related to the higher color levels and the greater organic contents associated with this coloration in the more western tributary. But these slightly reduced levels of summer DO would not be particularly significant relative to the stream's fishery with the DO concentrations at this time consistently above the minimum levels deemed desirable for cold water species (44). Of greater significance were the low winter DO levels and the high summer pH's and temperatures of the West Fork-IB which were most suggestive of a warm water, $B\text{-}D_3$ stream rather than a cold water fishery. The minimum cold weather DO points to a possible emigration of fish out of the upper segment at times during the winter season since this minimum value was below the critical DO concentration required for most game species (59). As observed for the East Poplar, therefore, but unlike the Middle Fork, levels of dissolved oxygen during the winter season also appeared to be a critical water quality parameter in the western portions of the upper Poplar drainage.

To some degree, the common constituent concentrations of the upper West Fork were generally similar to those obtained from the other branches of the Poplar River, although some obvious differences in these variables also became evident among the streams, between the West Fork and the East Poplar for example, in correspondence to the wide separation of the respective drainage areas of these two rivers. The upper West Fork waters were typically very hard and slightly saline through the winter season while being generally hard in nature and non-saline during the March to October period (10, 19, 58). Like the other Poplar tributaries, the West Fork also demonstrated a distinctive sodium bicarbonate-type of water with insignificant potassium, chloride, and fluoride concentrations. Sulfate and calcium-magnesium were again representative of the secondary anion and cations in the samples, and calcium and magnesium were found in roughly equal amounts over the entire year. In addition, concentrations of carbonate and the phenolphthalein levels of the stream were found to be relatively high on occasion in conjunction with the occurrence of high pH values in some of the summer samples. However, the upper West Fork tended to be more sodium bicarbonate in character than either the East or Middle Forks with higher sodium and bicarbonate concentrations and somewhat lower sulfate and calcium-magnesium concentrations in the first case through several seasons

of the year. This feature is also reflected in Table 25 by the comparitively high HCO_3/SO_4 and Na/(Ca + Mg) ratios in the upper West Fork versus those in the other streams.

Like the other Poplar streams, the upper West Fork was more sodium sulfate in nature during the winter and summer, low flow seasons than in the spring with higher Na/(Ca + Mg) ratios and lower HCO_3/SO_4 ratios at these times (Table 25). During the spring, the West Fork-IB waters became more calcium bicarbonate in composition with an increase in the stream's HCO_3/SO_4 and Ca/Mg ratios and a decline in its Na/(Ca + Mg) value. Regardless of these seasonal changes in chemical composition, and as a result of the higher overall concentrations of sodium in the upper West Fork, the samples from this particular reach had higher SAR's and higher %Na values than either of the other forks during all of the seasons. These high SAR and %Na values were slightly more pronounced in the West Fork-IB samples during the summer period in association with the low calcium concentrations of this season, possibly obtained as a result of biogenetic precipitation, and these aspects were least distinct during the spring runoff period in conjunction with the relatively low Na/(Ca + Mg) ratio. But outside of contributing to the upper West Fork's slightly higher salinity levels and its osmotic characteristics, the concentrations of the various individual constituents were not at adequate levels to affect the stream's aquatic biota to any significant degree. However, some of these constituents, such as sodium and sulfate, appeared to be in sufficient concentrations to possibly influence certain "outstream" water uses such as municipal supply and irrigation. These potential effects will be considered in a later chapter to this report.

Nutrients, metals, and other constituents.

Insufficient "field" parameter data are available (Table 44) with which to judge the organic pollution status of the upper West Fork Poplar River (i.e., a general lack of BOD and COD analyses), although the coliform assessments that were made for the stream samples do indicate an absence of major municipal effluents along its course. Some of the data in Table 45 can also be utilized for making these types of judgements, and this information suggests that the upper reach of the river is probably unaffected by organic pollution at the present time.

Like the East Poplar River, combined nitrogen concentrations were relatively high in the West Fork-IB samples, but the levels of these variables and ammonia were well below those concentrations that are commonly associated with mild municipal pollution (89). In turn, although TOC concentrations in the upper West Fork samples were somewhat higher than the values that might be expected from unpolluted, natural waters (10 mg C/l)(87), the West Fork levels of TOC were also well below those that can be obtained from mildly polluted streams; i.e., concentrations about equal to 100 mg C/l are typically obtained from weak domestic sewage (89) versus the 19 mg C/l median calculated for the study stream (Table 45). The somewhat high concentrations of TOC in the upper West Fork parallel the colored nature of its waters and the inputs of soil-related organic matter that could cause this coloration, and a further parallel of this kind is evidenced by the relatively high phenol concentrations observed for this particular segment of the Poplar drainage.

Table 45. Summary of chemical analyses of water collected from the West Fork Poplar River at the international boundary--nutrients, metals, and other constituents.

Stat	TN	TKjN	TON	NH_3N	NO_xN	TP	OP	COD	F	Si	D-B	D-Fe	T-Fe
November-February													
N.	4	7	4	7	7	7	7	0	7	7	7	4	1
Min	0.85	0.82	0.57	0.0	0.0	0.03	0.0	--	0.1	2.7	0.9	0.03	--
Max	1.8	2.4	0.98	0.82	2.3	0.08	0.12	--	0.8	30.	2.2	0.48	--
Mean	1.12	1.30	0.82	0.16	0.38	0.05	0.03	--	0.4	17.5	1.3	0.17	--
Med	0.92	1.2	0.85	<.01	0.06	0.04	<.01	--	0.5	15.8	1.1	0.08	0.21
March-May													
N.	3	5	3	5	5	5	3	0	5	5	5	5	1
Min	0.71	0.70	0.69	0.0	0.0	0.02	0.0	--	0.1	2.9	0.2	0.06	--
Max	1.1	1.5	1.1	0.01	0.10	0.15	0.04	--	0.5	11.	0.9	0.34	--
Mean	0.94	1.10	0.93	<.01	0.04	0.07	0.01	--	0.3	7.3	0.6	0.20	--
Med	1.0	1.1	1.0	<.01	0.01	0.06	0.0	--	0.3	8.2	0.6	0.18	0.31
June-October													
N.	5	8	5	6	10	9	6	0	10	10	6	7	2
Min	1.6	0.3	1.6	0.0	0.0	0.01	0.0	--	0.0	0.8	0.8	0.0	0.12
Max	1.9	2.0	1.9	0.05	0.25	0.14	0.03	--	0.8	21.	1.4	0.12	0.41
Mean	1.74	1.40	1.68	0.01	0.09	0.06	<.01	--	0.5	4.4	1.1	0.07	0.27
Med	1.8	1.6	1.6	<.01	0.1	0.05	<.01	--	0.4	2.0	1.1	0.07	0.27

Stat	D-Al	D-As	T-Ba	D-Be	T-Be	D-Cd	T-Cd	D-Cr	D-Cu	T-Cu
N.	4	8	1	5	3	6	4	4	6	3
Min	0.0	<.001	--	0.0	<.005	0.0	<.001	0.0	0.0	<.001
Max	0.05	0.005	--	0.010	<.005	0.001	0.002	0.010	0.002	0.002
Mean	0.02	0.002	--	<.004	<.005	<.001	0.001	0.005	0.001	0.001
Med	0.02	0.002	0.05	<.005	<.005	<.001	0.001	0.005	0.001	0.001

Stat	D-Hg	T-Hg	D-Li	D-Mn	T-Mn	D-Mo	D-Ni	D-Pb	T-Pb	D-Se
N.	4	2	4	6	4	4	4	4	4	9
Min	0.0	<.00005	0.09	0.0	<.010	0.0	0.001	0.0	<.004	0.0
Max	0.0003	<.00005	0.22	0.060	0.18	0.001	0.004	<.004	<.004	<.0005
Mean	<.0001	<.00005	0.16	0.020	0.07	<.001	0.003	<.002	<.004	<.0003
Med	0.0	<.00005	0.17	<0.012	0.051	0.0	0.003	0.003	<.004	<.0005

Stat	D-V	T-V	D-Zn	T-Zn	TOC	Phenols	Pesticides (ug/l)	Chl (ug/l)
N.	5	3	6	4	8	4	3	5
Min	0.0	<.001	0.0	<.001	6.	0.002	<.001	<1.
Max	0.0040	0.007	0.020	0.024	38.	0.013	0.02	<5.
Mean	<.0019	<.003	0.005	0.007	19.1	0.008	<.008	<4.2
Med	0.0023	<.001	<.001	0.003	19.	0.009	<.002	<5.

Similar to the humic and fulvic acids (and color), the phenols can also be derived from natural sources (33), as described previously, and this type of origin is also forecast for the West Fork-IB phenols instead of some polutive source. The phenols in the upper West Fork samples were not at adequate levels to cause a tainting of fish flesh or to adversely affect the aquatic biota (Table 15), but since the concentrations of this variable were consistently greater than the reference criteria for this constituent utilized by the Environmental Protection Agency (0.001 mg/1)(68), the phenols might be viewed as a critical water quality parameter in the upper reaches of the western Poplar tributary. That is, only a slight increase in the phenols over the naturally occurring, high background levels listed in Table 45 would be required to cause the development of fish tainting and toxicity problems.

Similar to several other streams in the Poplar drainage, the combined nitrogen and phosphorous species in the upper West Fork also tended to increase from the winter to the biologically active summer season as a result of the enhanced incorporation of nutrients into organic linkage during the warm weather period. In accord with this water quality change, the inorganic nitrogen and phosphorous concentrations of the water samples tended to be somewhat lower in the summer season than in the winter in association with the increases in biotic uptake of nutrients at this time. Like the other upper Poplar streams, orthophosphate concentrations were found to be largely insignificant, except possibly for the runoff periods, with the bulk of the stream's phosphorus assessed in the TP form. In the case of the upper West Fork, TP concentrations were closely equivalent through all seasons, and the winter low observed in the East Poplar for this constituent was largely absent from the western tributary. Mean and median concentrations of TP in the upper West Fork were either equal to or slightly above the lower reference criteria for phosphorous eutrophication in all seasons with 57% of the stream samples having TP concentrations in excess of 0.05 mg P/1; but this is suggestive of only a possibility of stream eutrophy since the upper reference value for phosphorus was exceeded in only 14% of the cases. In any event, the nitrogen factor also has to be considered when making water quality judgements of this kind.

As observed for the Middle Fork, ammonia and NO_XN concentrations in the upper West Fork were generally quite low with the stream's mean and median TIN levels well below the eutrophication criteria for the nitrogen nutrients, i.e., typically below 0.1 mg N/1. Only about 10% of the samples collected from the stream would be expected to have TIN concentrations in excess of 0.35 mg N/1. Although ammonia concentrations tended to be somewhat higher in the upper West Fork under the reducing conditions of winter than during the other seasons (Table 45), total ammonia would appear to be at insufficient levels to afford adequate unionized concentrations of this constituent to be toxic to aquatic organisms for any significant portion of the year, including the cold weather period. Such toxic conditions would occur primarily on a few sporadic occasions through the winter season. As a result of these features, and in contrast to the upper East Poplar, the West Fork at the IB might be graded as non-eutrophic with only about 6% of the samples collected from the stream expected to have both the nitrogen and the phosphorous nutrients in excess of their lower reference values; most of these high duo-nutrient collections would occur during the winter period.

The chlorophyll data that has been collected from the upper West Poplar (Table 45) demonstrated much lower values than those obtained from the more

eutrophic-prone East Poplar-IB (Table 22), and lower chlorophyll concentrations were obtained from the West Fork than the levels that have been shown to be common in mildly productive Montana lakes (81, 97). These data, therefore, like the nutrient information, also point to the non-eutrophic nature of the western tributary. Thus, eutrophy and ammonia toxicity do not appear to represent significant water quality problems in the West Fork drainage, and inorganic nitrogen inputs to the river in the form of NO_xN and/or NH_3N would have to be increased by a significant amount (in excess of ten-times) at the baseline phosphorous concentrations of the waters in order to produce continuous stream eutrophication and consistent ammonia toxicities. Like the rest of the upper Poplar drainage, the West Fork at the IB appears to be much more nitrogen- than phosphorous-limited through all of the seasons.

Boron and fluoride, along with ammonia, were also at inadequate levels to degrade the aquatic biota of the West Fork Poplar River in its border reach (Table 15), and this would apply to most of the trace elements analyzed for the stream as summarized in Table 45, including the pesticides. Two of the pesticide species, lindane and 2,4,5-T, went undetected in single West Fork samples, although one of the pesticides, 2,4-D, was detected in a single analysis in relatively low concentrations (0.02 ug/1). However, much higher concentrations of 2,4-D would be needed to adversely impact the stream's fishery and its other aquatic biota, as has been noted previously (41).

All of the metals listed in Montana's Water Quality Standards (44), with stream-specific, dissolved and/or TR reference criteria (Table 7), were also analyzed in samples from the West Fork-IB station and in samples from other sites in the Poplar drainage. With the exception of iron, none of these metals, i.e., As, Cd, Cu, Hg, Pb, and Zn, in the upper West Fork collections violated these particular State criteria, and this also appears to be the general rule for the entire upper Poplar Basin. In addition, five of these metals, excluding iron and mercury, also demonstrated TR and dissolved concentrations that were consistently beneath the corresponding reference criteria listed in Table 15. This latter observation also applies to Al, Ba, Be, Cr, Mn, Ni, and Se, and Li, Mo, and V can also be added to this list with their West Fork concentrations well below the levels of these constituents that have been deemed necessary to cause unfavorable biotic conditions (41, 93). As a result, these fifteen trace elements are non-indicative of water quality problems in the upper West Fork river, at least from the biological point of view, and this was found to be the case for the major portion of the upper Poplar drainage.

As described for the lower Middle Fork, mercury might be representative of a sporadic water quality problem in the upper segment of the western tributary with dissolved and thereby TR concentrations in a few of the collections in excess of 0.0002 mg/1. This was also found to be the case for iron with relatively high dissolved and TR concentrations obtained from some of the West Fork-IB samples in all seasons of the year. However, somewhat lower values for iron were typically observed under the oxidizing and low flow conditions of the summer season (Table 45), although iron levels appeared to be slightly higher in the upper West Fork than in the East Poplar River (Table 22). For example, about 25% of the West Fork-IB samples had D-Fe concentrations in excess of the Montana reference criterion listed in Table 7 (the maximum instantaneous concentration), versus a 9% value for the East Poplar. In contrast, concentrations of TR-Fe were not at adequate levels in the upper West Fork to violate the State's grab sample or average standard for total iron,

but the mean and median levels of D-Fe in the stream were sufficient in some of the seasons to violate the State's average criteria for the dissolved iron species. Although the mean and median concentrations of D-Fe at the West Fork-IB station were typically below its 0.2 mg/l reference value for freshwater aquatic life, approximately 19% of the samples from the stream did have D-Fe levels above this level with 19% having iron at "hazardous" concentrations; in turn, only 19% of the collections from the upper West Fork had D-Fe lower than the "minimal risk" levels specified for this parameter (Table 15). As a result of these features, iron might be viewed as an occasional problem parameter in the upper West Fork in relation to the aquatic biota, and this occurrence appears to be a common water quality aspect of the entire upper Poplar drainage.

The main action of iron in affecting the aquatic biota resides in the formation iron salt precipitates such as ferric hydroxide which can coat and irritate the gills of fish and block the respiratory channels of these finny critters and other aquatic macro-organisms (41). For example, concentrations of iron as low as 0.32 mg/l have been shown to have adverse effects on various aquatic insects such as the mayflies, stoneflies, and caddisflies (95). Therefore, an increase of dissolved iron in the upper West Fork on the order of three-times could greatly aggravate this presently sporadic problem to one that has more continuous effects. Greater increases of D-Fe over current levels (between three- and seven-times depending upon season) would be required for the East Poplar River in view of this river's generally lower baseline iron concentrations.

West Fork Poplar River near Four Buttes-Bredette

Field parameters and dissolved solids.

As indicated in Table 46, adequate data has been collected from the lower West Fork Poplar River at a variety of flow levels to allow for a seasonal plus flow classification of the lower West Fork stations' water quality information; this excludes only the extreme high flow category of the March to May period. As noted earlier, water quality data from two lower West Fork stations monitored by the United States Geological Survey were amalgamated to form the Four Buttes-Bredette (FBB) summary. The opportunity to conduct a flow classification for these two combined stations, in contrast to the IB site, was related to the marked downstream increase in West Fork flows between its IB station and the FBB location, and to the much higher flows that were obtained for the lower river throughout the year. Such greater downstream discharges, providing a 6.4-fold increase in the estimated average annual flow of the river (55), might be expected since a relatively long reach of the West Fork in Montana separates its IB and FBB sites in comparison to the shorter inter-station segments of the East and Middle Forks (Figure 1). As a result, a major portion of the West Fork waters arise within Montana rather than in Canada which stands in opposition to the case for the more eastern tributaries. For example, the East Poplar River demonstrated only a 1.5-fold increase in flows due to the inputs of water from Montana between the IB and Scobey. The lower West Fork flows obtained in conjunction with quality samples (Table 46) indicate that this stream is slightly larger than the other branches of the Poplar system, and this observation is confirmed by the slightly greater average annual flows obtained for this more western tributary (24,444 AFY) in relation to that in the other forks (about 20,000 AFY)(55). Like the other Poplar streams, a large

Table 46. Summary of chemical analyses of water collected from the West Fork Poplar River near Four Buttes-Bredette (lower reach)--field parameters and dissolved solids.

Stat	Flow	Temp	pH	Clr	Turb	TSS	SC	DS	DO--%Sat		BOD	TC	FC
November-February													
N.	6	6	4	0	4	0	6	6	4	4	0	1	1
Min	1.7	0.0	7.2	--	5.	--	990	638	7.2	54	--	--	--
Max	15.	4.5	8.4	--	50.	--	2150	1440	12.2	102	--	--	--
Mean	8.95	0.75	7.98	--	17.3	--	1262	830	9.6	75	--	--	--
Med	9.1	0.0	8.15	--	7.	--	1073	701	9.5	71	--	150	60
March-May (low flows)													
N.	5	8	6	0	4	2	8	8	5	3	0	2	3
Min	2.6	0.0	7.9	--	4.	8.	805	555E	8.4	90	--	<1	<1
Max	18.	23.5	8.63	--	15.	11.2	1150	861	11.8	127	--	55	19
Mean	10.8	12.4	8.31	--	7.8	9.6	962	643	9.7	103	--	28	7
Med	9.7	16.3	8.4	--	6.	9.6	950	606	9.8	93	--	28	<1
March-May (high flows)													
N.	4	4	3	0	1	3	4	4	1	0	1	0	0
Min	23	0.0	7.42	--	--	58.	236	183	--	--	--	--	--
Max	100E	6.0	7.91	--	--	84.	720E	497	--	--	--	--	--
Mean	67E	1.5	7.64	--	--	72.9	494	357	--	--	--	--	--
Med	73E	0.0	7.59	--	63	76.8	510	374	11.52	--	8.7	--	--
March-May (extreme high flows)													
N.													
Min													
Max						NO AVAILABLE DATA							
Mean													
Med													
June-October (low flows)													
N.	11	16	13	0	8	8	16	15	13	6	1	1	4
Min	0.0	6.5	8.1	--	3.7	4.	940	639	6.8	90	--	--	20
Max	15.E	30.0	9.3	--	100.	30.	1650	882	12.4	117	--	--	110
Mean	4.38	18.6	8.73	--	33.5	14.2	1175	766	9.4	101	--	--	67
Med	4.0	19.0	8.7	--	17.5	10.	1195	770	8.9	99	1.5	24	70
June-October (high flows)													
N.	2	2	2	0	2	1	2	2	1	1	0	0	0
Min	40E	23.7	8.52	--	27.	--	637	313	--	--	--	--	--
Max	150	25.5	8.6	--	45.	--	1066	915	--	--	--	--	--
Mean	95	24.6	8.56	--	36.0	--	852	614	--	--	--	--	--
Med	95	24.6	8.56	--	36.	20.	852	614	7.0	92	--	--	--

percentage of this annual discharge in the West Fork develops in association with the March-April, runoff period with average monthly flows at this time between 132 and 200 cfs; mean flows for the remainder of the year range between 0.6 cfs (mid-winter) and 27 cfs (late spring).

Daily flow data are not available for the lower West Fork stations by which to establish the percentage of days in a "typical" year falling into each of the season-flow categories defined previously, as has been done for the East and Middle Forks. However, the similarity of the seasonal discharge patterns among the various streams would indicate that the percentages developed for the other forks should also apply to the West Fork data, and this will provide a means for estimating the yearly weighted mean and median concentrational values for certain of the parameters assessed in the river. The percentages established for the Middle Fork can be reiterated as follows: November to February--32.9%, March to May (low flows)--15.4%, March to May (high flows)--6.5%, March to May (extreme high flows)--3.2%, June to October (low flows)--40.7%, and June to October (high flows)--1.2%. If anything, the percentage of high flow days in the West Fork will be slightly underestimated after applying these Middle Fork determinations, and this would tend to weight the statistical concentrations of some of the parameters such as DS and SC to somewhat higher numbers; however, this underestimation might also predict slightly lower weighted mean and median concentrations than the actual case for those variables that are directly related to flow, such as color, turbidity, and suspended sediment. Nevertheless, this approach will provide a means for establishing a single concentratial value for a parameter that should afford some insight into the possible overall effects of this variable on the aquatic biota.

In contrast to the downstream increase of DS-SC in the East and Middle Forks of the Poplar River, the West Fork demonstrated a decline in these variables between its IB and FBB stations. Such a dilution is indicative of a better quality of water in the Montana inputs to the fork than is found in the stream's headwaters area, and such downstream improvements of water quality have also been observed for other prairie streams in Montana (86). In addition, the DS-SC values of the WF-FBB samples were also somewhat lower than those obtained from the East and Middle Fork-Scobey locations. Using the percentages listed above, the weighted mean and median levels of DS-SC for the lower West Fork were estimated as follows: 726 mg/l and 681 mg/l, and 1100 umhos and 1045 umhos, respectively. These weighted statistics are between 18% and 26% lower than those calculated for the stream's upper station, and they are between 30% and 34% and between 21% and 29% lower than those obtained from the East Poplar and the Middle Fork near Scobey, respectively. As a result, the DS-SC values of the lower West Fork are indicative of a "generally excellent" class of fishery in the stream that is less marginal in relation to salinity than the fisheries that are contained in the other tributaries of the Poplar Basin. With the higher flows of the lower West Fork coupled with its lower DS-SC levels, this more southern stream should demonstrate a greater capacity than the Middle Fork for diluting any salinity impacts originating with the Coronach development in Canada and carried downstream to the Poplar River mainstem in Montana.

Like the other streams of the Poplar drainage, the West Fork Poplar River also demonstrated a fairly consistent inverse relationship between flow and DS-SC with lower levels of these variables obtained during high flow periods (Table 46). This is suggestive of a better quality of water in the stream during the higher discharge phases, although certain of the other parameters, pri-

marily those that are directly related to flow such as suspended sediment and turbidity, would tend to detract from the better qualities that are established under these conditions. In addition, DS-SC levels during the summer high flow periods, although lower than the values obtained in association with this season's low flow stages, were somewhat higher and demonstrated a worse quality of water than what might be expected on the basis of the flows that are in evidence at these times. This feature was also observed in the East Poplar River, and this parallels the fact that the summer high flows of the basin probably have somewhat different hydrological characteristics than the flows that are developed during the March-May, runoff season.

Although suspended sediment levels in the lower West Fork increased to some extent during the high flow periods, the maximum concentrations and the spring runoff values of this variable were probably not at adequate levels to detract from the stream's fishery to any significant degree. Levels of turbidity-suspended sediment appeared to be somewhat greater in the lower West Fork than in the other Poplar tributaries, but the differences in these constituents between streams were not all that distinct or consistent, varying by season, parameter, and statistic. However, suspended sediment would probably have a greater adverse effect on the lower West Fork fishery than would the stream's salinity levels since the yearly weighted mean and median values for turbidity (27 JTU and 17 JTU) are suggestive of only a good to moderate fishery in contrast to the "generally excellent" designation given to the stream on the basis of dissolved solids and specific conductance (Table 16). This stands in contrast to the East Poplar River which had lower weighted turbidity values than the West Fork-IB station with salinity described as the more limiting of the two variables in the more eastern stream. In any event, suspended sediment and turbidity were not representative of markedly critical water quality parameters in the West Fork or in the other major tributaries of the upper Poplar drainage; the levels of these parameters in the study area streams were quite low in comparison to the turbidity-suspended sediment values that have been obtained from other basically prairie systems in Montana, such as the Powder River, Rosebud Creek, and even the lower Yellowstone River (86). The upper Poplar Basin, therefore, might be rated as being a high quality drainage at the present time, at least from the standpoint of suspended matter and stream aesthetics. However, no color data are available for the West Fork-FBB station with which to determine if the colored natures of the IB samples were carried downstream into the lower segment of the river.

For the most part, descriptions of the other "field" parameters assessed in the lower West Fork samples would generally follow that presented in the previous section for the river's upper sampling station. This would include the low coliform concentrations, indicating an absence of municipal pollution, the DO-%Sat values (except for the winter period), and the levels of pH and temperature. A slight depression of DO concentrations was also evident in the lower West Fork during the winter season, but this was obvious only in terms of the %Sat figures. This seasonal, downstream depression in oxygen was much less distinct than that observed at the IB with DO concentrations in the lower reach during all seasons, including the cold weather period, typically above the State's criterion for a cold water fishery and well above the standard for a warm water stream (44). In no cases were DO levels adequately low to force the emigration of game fish species out of the lower West Fork reach (59). Insufficient BOD have been collected by which to de-

termine the organic pollution status of the stream, but the low coliform levels and these generally high DO levels would indicate that this was probably not an important factor in the West Fork drainage. Regardless of the amenable DO concentrations, however, the winter to summer increases in pH and temperature and the relatively high levels of these two variables during the warm weather season would point to the occurrence of either a warm water or, at best, a marginal cold water fishery in the lower West Poplar River. Although the minimum levels of pH were nondistinctive, values of pH in several of the summer samples were adequately high to degrade a good fishing water (88).

As indicated in Tables 46 and 47, the winter and spring temperatures of the lower West Fork would appear to be noncritical in relation to affecting a cold water fishery since relatively low mean and median values were obtained during these seasons. In contrast, the median temperature of the warm weather, June to October period was considerably higher and closely equivalent to the 19.4C reference criterion for a cold water, $B\text{-}D_1$ or $B\text{-}D_2$ stream (44). In addition, a fairly large percentage of the summer temperature readings exceeded this reference value (near 50%), including about 13% the temperatures taken during the spring season, and this would indicate that the lower West Fork was probably not representative of a cold water river. The State of Montana, in turn, describes the West Fork as having a marginal $B\text{-}D_2$ water (44) which coincides with the fork's median warm weather temperature; but this designation, assuming the marginal propagation of cold water species, is possibly in error since between 6% and 63% of the maximum June to October temperature readings (91) from the stream and between 11% and 44% of its grab sample temperatures in this season exceeded the juvenile tolerance limits (78, 82, 84) for Montana's common salmonid fishes such as rainbow, brown, and brook trout (with the percentage varying by species). Although a planted or migratory population of adult salmonids might survive in the Poplar West Fork, such high summer temperatures would probably preclude their successful propagation. However, only a very few of the temperatures taken from the lower West Fork exceeded the State's $B\text{-}D_3$, 26.7C criterion (Table 47), and less than one percent of the lower river temperatures were in excess of the tolerance limits for one of the most thermally sensitive of the warm water species, the fathead minnow (85). As a result of these features and the stream's pH characteristics, the West Fork is probably best classified as a $B\text{-}D_3$ stream, and this appears to be the general case for the entire upper Poplar drainage. Species composition data from the various fishery surveys being conducted in the Poplar Basin will more definitely categorize the upper streams of the region in this regard.

Common constituents.

In contrast to the East and Middle Forks of the Poplar River, many of the common constituents in the West Fork demonstrated a downstream decline in concentrations in correspondence to the drop in salinity between the IB and the FBB stations. As a result of this feature, the lower West Fork was largely non-saline for a major portion of the year (58), and depending upon flow, it demonstrated moderately hard to hard waters (10, 19), rather than the very hard waters of the other forks, because of its reduced calcium and magnesium concentrations (Table 48). Sulfate levels were also generally lower in the West Fork-FBB samples than in the other Poplar streams.

Table 47. Temperature characteristics of the lower West Fork Poplar River near Four Buttes-Bredette expressed as the percentage of readings falling within various temperature ranges specified for cold water (19.4C) and warm water (26.7C) fisheries; minimum, maximum, and median values are also listed. Data were taken from (1) various sources and from (2) unpublished records collected by the Montana Department of Fish and Game (Needham, 1977).

Period of Observations	Temperature Range or Statistic	Winter November-February	Runoff March-May	Warm-Weather June-October
Grab sample temperatures (1): October, 1974 to August, 1977	<19.4C	100%	92%	50%
	19.4C to 26.7C	0%	8%	39%
	>26.7C	0%	0%	11%
	Minimum	0.0C	0.0C	6.5C
	Maximum	4.5C	23.5C	30.0C
	Median	0.0C	7.3C	20.0C
	Sample Number	6	12	18
Continuous daily records (2): April, 1976 to November, 1977				
Maximum temperatures	<19.4C	100%	82%	47.4%
	19.4C to 26.7C	0%	18%	51.3%
	>26.7C	0%	0%	1.3%
	Minimum	1.1C	6.1C	0.6C
	Maximum	6.7C	22.8C	28.3C
	Median	3.6C	15.0C	19.4C
	Sample Number	20*	111**	304
Minimum temperatures	<19.4C	100%	100%	88%
	19.4C to 26.7C	0%	0%	12%
	26.7C	0%	0%	0%
	Minimum	0.0C	2.8C	0.0C
	Maximum	4.4C	17.8C	22.2C
	Median	1.7C	10.8C	15.0C
	Sample Number	21*	110**	303

*Month of November only. **Excludes the month of March.

Table 48. Summary of chemical analyses of water collected from the West Fork Poplar River near Four Buttes-Bredette (lower reach)--common constituents.

Stat	CO_2	HCO_3	CO_3	TA	PA	Cl	SO_4	Ca	Mg	TH	Na	SAR	%Na	K
November-February														
N.	4	6	4	6	0	6	6	6	6	6	6	6	6	6
Min	3.2	509	0.0	417	--	5.6	120	17.	11.	88	190	6.0	65.	3.2
Max	105.	1040	0.0	853	--	24.	380	69.	59.	420	370	9.8	83.	9.5
Mean	30.9	666	0.0	546	--	9.1	175	34.7	25.3	191	242	8.0	73.8	5.0
Med	7.7	611	0.0	501	--	6.3	140	31.5	21.	165	215	8.3	74.	4.3
March-May (low flows)														
N.	3	6	4	6	0	6	6	6	6	6	8	6	5	5
Min	2.1	450	0.0	389	--	4.4	64	16.8	14.1	100	139	5.3	66.	3.9
Max	3.8	570	31.	470	--	6.4	150	35.	22.	170	240	10.	82.	5.9
Mean	2.9	517	12.	437	--	5.6	106	23.6	17.0	128	184	7.6	74.4	4.6
Med	2.9	535	8.	440	--	5.6	99	20.	15.	110	174	7.8	76.	4.1
March-May (high flows)														
N.	0	4	4	4	0	4	4	4	4	4	4	4	1	4
Min	--	110	0.0	91	--	1.1	21	13.5	2.2	52	24	1.4	--	5.6
Max	--	425	21.	384	--	4.6	150	29.	20.	150	130	4.5	--	7.9
Mean	--	220	5.3	190	--	3.2	71	20.7	9.7	90	77	3.4	--	6.8
Med	--	173	0.0	142	--	3.6	56	20.2	8.2	80	76	3.8	64	6.9
March-May (extreme high flows)														
N.														
Min														
Max						NO AVAILABLE DATA								
Mean														
Med														
June-October (low flows)														
N.	6	9	7	10	0	10	10	16	16	9	16	9	8	9
Min	2.0	433	12	420	--	0.5	100	8.8	11.	87	170	5.5	67.	4.2
Max	3.4	650	48	570	--	7.8	180	31.	25.	180	310	14.	88.	6.9
Mean	2.6	568	27	501	--	5.9	139	16.5	16.9	118	252	10.1	80.9	5.2
Med	2.4	573	22	509	--	6.4	140	15.5	16.	100	259	11.	84.	4.9
June-October (high flows)														
N.	1	2	2	2	0	2	2	2	2	2	2	2	1	2
Min	--	356	0.0	292	--	3.6	54	24.	14.	120	100	4.0	--	6.0
Max	--	501	11.	429	--	5.0	150	25.1	21.2	150	195	6.9	--	7.1
Mean	--	429	5.5	361	--	4.3	102	24.6	17.6	135	148	5.5	--	6.6
Med	1.4	429	5.5	361	--	4.3	102	24.6	17.6	135	148	5.5	63	6.6

To a large degree, the distinctive ionic composition characteristics of the upper West Fork (Table 44) were carried downstream into the river's lower reach. This was most obvious in terms of the marked dominance of the sodium and bicarbonate ions and in terms of the more pronounced sodium bicarbonate nature of the lower West Fork over the other drainage waters. This feature is also evident in Table 25 through the comparatively high HCO_3/SO_4 and Na/(Ca + Mg) ratios of the lower West Fork samples. Like the upper West Fork, SAR and %Na values were also comparatively high in the lower reach of the river (Table 48) in relation to the values of these parameters in the other upper Poplar streams, and this stems from the West Fork-FBB's high sodium and low total hardness concentrations. In contrast to sodium, sulfate and calcium were representative of secondary ions in the lower West Fork samples while potassium and chloride concentrations were again largely insignificant. Occasionally high carbonate and carbon dioxide levels were obtained from the stream in conjunction with the high and low pH values of the summer and winter seasons respectively, but like the case for chloride, these constituents were also largely nondistinctive. Similarly, magnesium concentrations, on a weight basis, were typically considerably less in the lower West Fork for most of the year than the levels of calcium in this reach, as illustrated by the Ca/Mg ratios of Table 25, and in some seasons, magnesium was at adequately low levels to be viewed as insignificant from a water quality point of view. Such low magnesium concentrations, therefore, would further characterize the lower West Fork in relation to the other Poplar tributaries. The relatively low calcium concentrations of the June to October, warm weather season and the uniquely low Ca/Mg ratio of the lower West Fork at this time might have been related to a biogenetic precipitation of calcium during this high pH, summer season, as has been described previously.

Another distinctive feature of the West Fork of the Poplar drainage resides in the fact that this stream becomes more sodium bicarbonate in character with proportionately higher calcium concentrations in a downstream direction from the IB. This is evidenced in Table 25 by the general increases in the West Fork's HCO_3/SO_4, Na/(Ca + Mg), and Ca/Mg ratios between the IB and FBB stations. This aspect of the West Fork stands in contrast to the tendency of the East Poplar to become more sodium sulfate in character downstream with proportionately greater concentrations of magnesium near Scobey. Such differences between streams are suggestive of a different source of baseline flow inputs to the West Fork between its upper and lower stations than the inputs that enter the East Poplar River in Montana, which in turn corresponds to the geographic separation of the East Poplar drainage from the more southern drainage of the western tributary. The baseline inputs to the East Poplar would appear to be more sodium-magnesium sulfate in nature in contrast to the more sodium-calcium bicarbonate-type of waters that develop within the West Fork sub-basin.

As a related point of difference between the Poplar tributaries, waters in the West Fork became quite calcium sulfate in character during the high flow, spring runoff period relative to the stream's low flow samples which were much more sodium bicarbonate in composition (Table 25). This feature also stands in contrast to the other Poplar streams, such as the Middle Fork, which developed a proportionately higher bicarbonate level and a higher HCO_3/SO_4 ratio during this runoff period than during the remainder of the year. This latter inter-stream difference is probably another water quality reflection

of the geographic and geologic separation of the West Fork and the East-Middle Forks drainage areas. But regardless of these various inter-stream differences and downstream quality changes, the common constituents in the lower West Fork, as observed for the other tributaries, would probably not affect the aquatic biota to any significant degree on an individual basis. However, other water uses in the drainage might be affected by the West Fork's somewhat unique quality characteristics, e.g., an effect on irrigation in relation to the stream's relatively high sodium, SAR, and %Na values.

Nutrients, metals, and other constituents.

Although boron concentrations in the lower West Fork (Table 49) were considerably above Montana's surface water average for this constituent (12), they were significantly lower than the boron levels in the other streams of the Poplar drainage as a result of the distinct downstream decline in this constituent from the West Fork's IB station to its FBB site. These observations indicate that the bulk of the boron in Poplar system probably arises from the headwaters, Canadian portion of its basin with comparatively little of this variable entering the streams from the Montana side of its drainage. This factor coupled with the large inter-station flow inputs noted previously would produce the marked downstream decline observed for boron in the Poplar Basin's more southwestern tributary. The dilution of boron in the West Fork was quite pronounced because of this stream's relatively extensive Montana drainage area between its two sampling stations in comparison to that of the other Poplar streams.

Like the Middle Fork and the East Poplar River, boron in the lower West Fork was not at adequate levels to adversely affect the aquatic biota (98), and this conclusion also applies to fluoride, which was found to be an insignificant ionic component of the lower reach, and to most of the trace elements listed in Table 50. That is, the dissolved concentrations of most of these constituents were either well below the reference criteria summarized in Table 15, or in the case of Li, Mo, and V, well below the extremely high concentrations of these elements that are required to invoke toxic effects in aquatic organisms (41, 92). This observation also applies to those metals that demonstrated relatively high total recoverable concentrations in some of the West Fork-FBB samples, such as iron (Table 49), aluminum, and manganese. As described for the upper West Fork, but excluding iron which had relatively low dissolved concentrations downstream, mercury apparently affords the only exception for the lower West Fork with a few samples having mercury levels in excess of its reference criteria. Similar to many of the drainages in Montana, mercury appears to provide a potential, but most likely, only an occasional water quality problem to the western segment of the Poplar Basin.

In contrast to boron, silica levels in the lower West Fork were closely equivalent to the State average for this constituent (12). No distinct seasonal trends became evident for this constituent (Table 49) as has been observed for the East Poplar, although silica concentrations did tend to decline to some extent at the FBB station during the spring period, possibly as a result of runoff dilutions, and they also declined slightly from the winter to the summer season possibly in response to a periphyton utilization during the warm weather months. However, such seasonal changes were

Table 49. Summary of chemical analyses of water collected from the West Fork Poplar River near Four Buttes-Bredette (lower reach)--nutrients and other constituents.

Stat	TN	TK_jN	TON	NH_3N	NO_xN	TP	OP	COD	F	Si	D-B	D-Fe	T-Fe
November-February													
N.	4	4	4	4	6	4	6	0	6	6	6	6	0
Min	0.21	0.20	0.20	0.0	0.0	0.02	0.0	--	0.2	7.4	0.4	0.01	--
Max	0.94	0.93	0.93	0.25	0.11	0.21	0.12	--	0.9	17.	1.9	0.20	--
Mean	0.60	0.57	0.50	0.07	0.03	0.09	0.02	--	0.5	10.3	0.7	0.06	--
Med	0.63	0.57	0.39	0.01	0.01	0.06	0.01	--	0.4	9.7	0.5	0.025	--
March-May (low flows)													
N.	3	3	3	4	5	4	6	0	6	5	5	5	1
Min	0.16	0.16	0.16	0.0	0.0	0.01	0.0	--	0.4	5.7	0.3	0.02	--
Max	0.36	0.35	0.34	0.01	0.02	0.04	0.02	--	0.5	9.7	0.5	0.18	--
Mean	0.27	0.26	0.26	<.01	0.01	0.02	0.01	--	0.4	7.5	0.4	0.06	--
Med	0.30	0.28	0.27	<.01	0.01	0.01	0.01	--	0.4	7.9	0.4	0.04	0.24
March-May (high flows)													
N.	0	1	0	3	4	3	4	0	4	1	1	1	2
Min	--	--	--	0.04	0.0	0.20	0.01	--	0.1	--	--	--	0.02
Max	--	--	--	0.13	0.79	0.33	0.21	--	0.4	--	--	--	0.05
Mean	--	--	--	0.10	0.44	0.25	0.10	--	0.2	--	--	--	0.035
Med	--	2.4	--	0.12	0.48	0.22	0.08	--	0.1	7.6	0.3	0.13	0.035
March-May (extreme high flows)													
N.													
Min													
Max						NO AVAILABLE DATA							
Mean													
Med													
June-October (low flows)													
N.	6	7	6	7	10	7	9	0	9	8	8	8	9
Min	0.48	0.29	0.40	0.0	0.01	0.02	0.0	--	0.4	6.3	0.6	0.02	0.17
Max	0.77	0.75	0.69	0.06	0.17	0.12	0.02	--	0.6	9.3	0.8	0.08	1.3
Mean	0.61	0.53	0.56	0.01	0.04	0.07	0.01	--	0.5	7.8	0.6	0.05	0.45
Med	0.60	0.55	0.57	<.01	0.02	0.07	0.01	--	0.5	8.2	0.6	0.04	0.25
June-October (high flows)													
N.	1	2	1	2	2	2	2	0	2	1	1	1	1
Min	--	0.45	--	0.0	0.01	0.05	0.026	--	0.3	--	--	--	--
Max	--	0.95	--	0.085	0.02	0.09	0.04	--	0.37	--	--	--	--
Mean	--	0.70	--	0.043	0.015	0.07	0.033	--	0.34	--	--	--	--
Med	0.95	0.70	0.94	0.043	0.015	0.07	0.033	--	0.34	14.	0.4	0.12	1.1

Table 50. Summary of chemical analyses of water collected from the West Fork Poplar River near Four Buttes-Bredette (lower reach)--metals and miscellaneous constituents.

Stat	TOC	D-Al	T-Al	D-As	T-As	T-B	T-Ba	D-Be	T-Be
N.	1	5	9	5	10	12	1	5	2
Min	--	0.0	<.01	0.001	<.001	<.1	--	0.0	0.0
Max	--	0.05	0.97	0.003	<.025	1.35	--	0.01	<.01
Mean	--	0.02	0.31	0.002	<.016	0.65	--	0.002	<.005
Med	12	0.02	0.30	0.002	<.025	0.48	0.1	0.0	<.005

Stat	D-Cd	T-Cd	T-Co	D-Cr	T-Cr	D-Cu	T-Cu	D-Hg	T-Hg
N.	5	7	1	5	4	5	13	5	6
Min	0.0	<.001	--	0.0	<.05	0.0	<.002	0.0	0.0
Max	0.0	<.01	--	0.004	<.05	0.002	0.01	0.0015	<.0002
Mean	0.0	<.002	--	0.001	<.04	0.001	<.01	0.0003	<.0002
Med	0.0	<.001	<.01	0.0	<.05	0.0	<.01	0.0	<.0002

Stat	D-Li	T-Li	D-Mn	T-Mn	D-Mo	T-Mo	D-Ni	T-Ni
N.	5	2	14	7	5	2	5	2
Min	0.08	0.10	0.0	0.03	0.0	0.0	0.002	<.01
Max	0.11	0.10	0.05	0.42	0.002	<.10	0.006	<.05
Mean	0.10	0.10	0.016	0.12	0.001	<.05	0.003	<.03
Med	0.11	0.10	0.015	0.08	0.001	<.05	0.002	<.03

Stat	D-Pb	T-Pb	D-Se	T-Se	T-Sr	D-V	T-V	D-Zn	T-Zn
N.	5	6	5	11	0	5	2	5	13
Min	0.0	<.005	0.0	0.0	--	0.0	<.10	0.0	<.005
Max	0.001	<.100	0.0	<.01	--	0.0026	<.11	0.01	0.03
Mean	0.0002	<.05	0.0	<.006	--	0.001	<.105	0.007	<.01
Med	0.0	<.05	0.0	<.01	--	0.0005	<.105	0.01	<.01

not as distinct in the lower West Fork as those noted for the East Poplar, and they were not as obvious as those observed for the West Fork at its IB station (Table 45). This latter aspect is possibly related to the much larger flows and water volumes that are developed in the West Fork-FBB reach producing a lower stream bed surface area (periphyton habitat) per river volume ratio in this instance than at the IB; this would result in lower rates of exposure downstream for any given unit of river water to the periphyton colonizing the river substrate. These features, in turn, would reduce the amount of silica that can be pulled out of any particular volume of water by the FBB reach diatoms in relation to the case for those in the IB reach with its shallower and smaller volume characteristics. Such enhanced upstream losses of this constituent by diatom utilization during the summer months were apparently supplanted to a large degree above the river's mouth by the intermediate baseline inputs of water that would be expected to have fairly high levels of silica. At the lower West Fork station, therefore, silica was not at appropriate levels to limit diatom growth (80), but this would also apply to the river's upstream segment regardless of the marked drop in silica that was observed for the summer period. Thus, this constituent might be viewed as an uncritical water quality variable in the West Poplar River.

Concentrations of the combined nitrogen species declined downstream in the West Fork from the IB to the FBB station, but a consistent pattern of this nature was not evident in the river with respect to the phosphorous variables. Like the upper West Fork, orthophosphate was again largely insignificant in the FBB reach with the bulk of the phosphorus found in the combined form (Table 49). In contrast to the distinct downstream changes in total nitrogen, for example, obvious seasonal alterations in the combined versus the inorganic nitrogen and phosphorous concentrations were not readily evident in the lower West Fork as has been observed in several of the other Poplar streams. However, the levels of the combined nitrogen and phosphorous species did tend to be somewhat lower during the spring than during the summer and winter, and generally higher concentrations were obtained during the runoff periods over the rest of the year. But in all of these instances, combined nitrogen was not at adequate levels to be suggestive of organic pollution, and this conclusion is supported by the single total carbon analysis performed for the river (Table 50) which demonstrated low organic concentrations.

Mean and median concentrations of the inorganic nitrogen and phosphorous species (Table 49) were generally constant throughout most of the year except for the brief increases in these variables that occurred during the high flow periods probably in conjunction with nutrient enrichments from overland flow; such inputs would also account for the increases in the combined species that were noted under runoff conditions. But outside of these runoff stages, the lower West Fork can be graded as non-eutrophic because of its low ammonia and nitrite-nitrate concentrations and because of the low TIN levels that were typically obtained from the river; these values were well below the lower reference criterion for nitrogen eutrophication. In turn, the river can be rated as more nitrogen than phosphorous limited since its TP concentrations, in contrast to its TIN levels, were typically above the corresponding reference criterion for this particular nutrient, excluding the spring season. As a result of these features, the major nutrients in the lower West Fork, unlike the upper East Poplar, are not suggestive of water quality problems or degradations, either from a eutrophic standpoint

or from the viewpoint of ammonia toxicities. On this basis, therefore, and in relation to most of the water quality variables monitored for the Poplar Basin, the lower West Fork of the Poplar River would appear to have a generally good quality of water at the present time.

POPLAR RIVER MAINSTEM

Middle Reach Poplar River near Bredette

Field parameters and dissolved solids.

The Bredette sampling station on the middle reach of the Poplar River mainstem is located above the West Fork and about 20 miles (32 kilometers) below the point where the East Poplar River and the Middle Fork join to form the main river. As a result, flows at this middle reach station should be considerably higher than those in either of the two upstream tributaries and generally equal to their combined discharges plus whatever water inputs enter the river between the Bredette station and the forks' confluence near Scobey. Flows obtained in conjunction with the quality sampling on the Poplar mainstem near Bredette were typically greater in each season than those obtained from either of the forks, but exceptions did become evident in this regard possibly coincidental with the relatively small amounts of quality data that had been collected from this particular mainstem site. Nevertheless, adequate quality information was available to allow for a seasonal-flow separation of the data as summarized in Table 51. However, daily discharge data have not been collected from the Bredette mainstem station by which to establish the percentage of days falling into each of the season-flow classes; therefore, the yearly weighted mean and median values of certain of the parameters monitored at the Poplar River-Bredette location will have to be estimated by using an average of such percentages established previously for the two upstream forks. These percentages can be listed as follows: November to February--32.9%, March to May (low flows)--16.5%, March to May (high flows)--5.8%, March to May (extreme high flows)--2.9%, June to October (low flows)--40.6%, and June to October (high flows)--1.4%.

As indicated in Table 51, the middle reach of the main Poplar is a fairly large stream on the basis of discharge in comparison to its two upstream forks with the mean and median flows at the Bredette station typically greater than 5 cfs throughout the year. Similar results, except for the month of January, were obtained by the United States Geological Survey in their natural flow estimations (55). The USGS estimated the average flow of the middle river through the warm weather season at 26 cfs and that for the winter period at 6.6 cfs. Even under minimum discharge conditions, flows in this Poplar segment were typically greater than one cfs for all months except for the January to March period when they equalled about 0.3 cfs (55). As a result, flow would not represent as critical of a variable to the stream's fishery in this middle reach as the case noted for the East and Middle Forks, particularly at the tributaries' IB locations. Like the other Poplar streams, a large proportion of the Poplar-Bredette annual discharge occurs during the spring period of March to May with mean monthly flows ranging between 66 cfs and 365 cfs at this time; high and low extremes of 0.4 cfs and 2774 cfs have been observed for these three months (55). About 80% of the average annual discharge of the middle Poplar River develops during this spring season.

Table 51. Summary of chemical analyses of water collected from the Poplar River near Bredette (middle reach, main river above the West Fork)--field parameters and dissolved solids.

Stat	Flow	Temp	pH	Clr	Turb	TSS	SC	DS	DO	%Sat	BOD	TC	FC
November-January													
N.	4	4	4	0	4	0	4	4	4	4	0	0	0
Min	8.0	0.0	7.7	--	3.	--	1620	1100	8.4	63	--	--	--
Max	19.	4.5	8.5	--	6.	--	2700	1900	11.6	97	--	--	--
Mean	11.6	1.3	8.05	--	4.0	--	1970	1340	10.0	77	--	--	--
Med	9.6	0.3	8.0	--	3.5	--	1780	1180	9.9	74	--	--	--
March-May (low flows)													
N.	3	5	5	0	3	3	5	5	3	1	0	0	0
Min	5.E	15.5	7.4	--	11.	21.	925	556	8.1	--	--	--	--
Max	16.	23.0	8.40	--	20.	36.2	1500	1370	9.8	--	--	--	--
Mean	9.0	17.8	8.09	--	15.3	29.7	1194	996	9.0	--	--	--	--
Med	6.E	16.9	8.33	--	15.	31.9	1270	1023	9.0	126	--	--	--
March-May (high flows)													
N.	3	3	3	0	3	1	3	3	2	2	0	0	0
Min	25.	0.0	7.55	--	5	--	201	141	9.0	80.	--	--	--
Max	51.	6.5	8.5	--	1100	--	1150	786	10.6	81.	--	--	--
Mean	33.7	2.2	8.08	--	371	--	780	512	9.8	80.5	--	--	--
Med	25.	0.0	8.2	--	7	780	990	608	9.8	80.5	--	--	--
March-May (extreme high flows)													
N.													
Min													
Max						NO AVAILABLE DATA							
Mean													
Med													
June-October (low flows)													
N.	7	7	7	0	7	2	7	7	7	5	2	1	4
Min	3.6	7.5	8.5	--	3.	35.5	1120	729	7.6	88	2.6	--	40
Max	15.	23.0	8.8	--	50.	52.4	1710	1150	11.0	107	2.6	--	75
Mean	7.2	15.8	8.67	--	21.3	44.0	1514	1019	9.4	98	2.6	--	58
Med	5.E	14.5	8.7	--	16.	44.0	1560	1070	9.0	98	2.6	39	58
June-October (high flows)													
N.	6	6	6	0	3	4	6	6	4	2	0	0	0
Min	24.0	17.5	7.0	--	20.	18.	812	512	6.2	78	--	--	--
Max	300.	28.	8.9	--	240.	72.	2200	1480	7.6	85	--	--	--
Mean	69.6	21.7	8.35	--	98.7	39.3	1695	1175	6.9	81.5	--	--	--
Med	34.5	22.0	8.49	--	36.	33.5	1775	1342	7.0	81.5	--	--	--

Estimated natural yearly flows for pertinent sites in the Poplar drainage (55) indicate that 40% of the Bredette mainstem flows (47,509 acre-feet per year) is due to the East Poplar River with 45% due to the Middle Fork waters. As a result, a 50% reduction in East Poplar discharge should produce a 20% decline in the annual flow of the Poplar mainstem near Bredette. However, this downstream discharge contribution varied considerably between the two streams with the major delivery of the Middle Fork occurring during the spring and early summer seasons and with the East Poplar making a greater contribution than the Middle Fork to mainstem flows during the late summer, fall, and winter periods. Thus, the decline in Poplar discharge at Bredette in response to any East Poplar flow reductions would be most pronounced during the late summer through late winter period and least distinct during the spring and early summer months. Only about 15% of the Bredette flow is due to water inputs downstream of the two forks below Scobey. Therefore, the quality features of samples from the Bredette mainstem station should be primarily a composite of that in the two forks, unless these downstream inputs have significantly higher concentrations of particular water quality variables than the major tributaries, thereby producing a distinct loading effect on the Poplar waters below Scobey.

Inadequate BOD_5 and coliform data are available for the middle Poplar River to definitely determine the organic and municipal pollutional status of this particular reach, although the data of this kind that are at hand would suggest that these features are not a problem to the Poplar mainstem in view of the river's apparently quite low BOD_5 and coliform concentrations (Table 51). This is generally supported by the relatively high dissolved oxygen concentrations of the middle reach with levels well above Montana's fairly rigorous DO criteria for a cold water stream in all instances (44). On the basis of %Sat, a slight winter depression in DO was again evident, as observed for many of the other Poplar area streams, but on the basis of DO per se, this depression was noncritical in the mainstem in contrast to the more distinct reductions of this variable that were obtained for many of the smaller streams which pointed to the possible forced emigration of sport fish out of these tributary waters. Although oxygen in the middle Poplar appeared to be noticeably less than 100% of saturation as a standard case throughout the year, this occurrence was most likely due to natural factors rather than to man's activities, and it was apparently unimportant from a biotic point of view.

But regardless of the high DO levels, the increases in temperature and pH from the winter to the summer season, the latter probably occurring at least in part from the in situ photosynthetic utilization of stream bicarbonate, and the high warm weather values of these two parameters would indicate that the middle Poplar, like the lower West Fork, is best described as a warm water, $B\text{-}D_3$ stream instead of a cold water, $B\text{-}D_1$ or marginal $B\text{-}D_2$ river. Minimum pH levels were also nondistinctive in this middle reach, but the high pH's of the waters were somewhat extreme on occasion, as noted for some of the other Poplar drainage streams, and indicative of potential water quality degradations relative to the river's fishery (88). As suggested by Montana's Water Quality Standards (44), such high pH's would be more conducive to a warm water fishery over the cold water form.

Turbidity-suspended sediment levels in the middle reach of the Poplar River were quite variable within and between seasons as illustrated by the

wide discrepancy between the mean and median, yearly weighted turbidity values that were obtained for the Bredette site, i.e., 46 JTU and 11 JTU respectively. No obvious trends in these two variables became evident between the two upstream forks and the Poplar mainstem, although distinctively high turbidity-suspended sediment levels were observed in some of the samples collected from the middle reach during runoff events, e.g., turbidities in excess of 230 JTU and approaching 1100 JTU, equivalent to 1105 mg/l and 5455 mg/l respectively, and analyzed suspended sediment concentrations approaching 780 mg/l. Such values would indicate that significant pulses of suspended sediment are developed in the main Poplar River on occasion pointing to the possibility of some fishery and aesthetic degradations on this particular basis. These types of sporadic degradations appeared to be largely absent from the tributary streams. During runoff periods, therefore, turbidity-suspended sediment levels apparently increase from the upstream forks to the Bredette mainstem station whereas only small and variable downstream changes in these parameters are apparent during the low flow seasons. However, data for turbidity and suspended sediment are relatively unabundant for the mid-Poplar, and additional collections will have to be made to definitely establish the duration and magnitude of this potential problem in the middle stretch of the river. The yearly weighted mean and median values for turbidity listed above indicate a fair to good fishery in the mainstem relative to suspended sediment (25), but this rating is dependent upon the statistic being used. In addition, the low weighted median value for turbidity (11 JTU) would provide a fairly high, overall aesthetic grading to the stream.

The DS-SC levels of samples collected from the middle Poplar River near Bredette (Table 51) indicate that the waters of this reach were slightly saline (58) through a major portion of the year. The only exception occurred during the spring runoff period when the river was non-saline for a short period of time in association with the inverse relationship between flow and dissolved solids. But similar to the East Poplar, unexpectedly high DS-SC levels in relation to flow were obtained from the middle reach of the main Poplar during the warm weather runoff events; apparently this feature was carried downstream into the mainstem from its eastern tributary.

As suggested previously, DS-SC levels in the mid-Poplar would be expected to be quite similar to a composite of those obtained for the two upstream forks (Tables 23 and 39). This was generally in evidence for the winter and summer seasons where mean and median DS and SC levels for the Bredette station were about equal to those obtained from the Scobey sites on the two forks; only a 1.1% average difference in mean and median DS-SC was obtained between the Bredette samples and the corresponding means of the lower Middle and East Fork values during these two periods. On a yearly basis, however, the weighted mean and median DS-SC levels of the mid-Poplar collections were about 7.3% higher than an average of these values from the two forks because of the higher spring levels that were obtained from the larger stream. That is, during the spring season, DS-SC levels of the middle reach were about 19% greater than a composite for the two tributaries in this same period. As a result of these features, inputs of water to the middle segment of the Poplar per se, accounting for 15% of the river's annual flow at Bredette, apparently have a relatively minor effect on the mainstem's quality during the months of June to February while having a slight effect in increasing mainstem salinities during the spring period with this particular season's higher flow and lower salinity characteristics. Loading cal-

culations indicate that the yearly weighted median DS concentration of these intermediate input waters below Scobey would be assessed in the area of 1630 mg/l.

The yearly weighted mean and median values for DS and SC in the middle Poplar reach near Bredette were calculated as 1080 mg/l and 1063 mg/l and as 1551 umhos and 1540 umhos respectively. As indicated in Table 16, these values would be suggestive of a good fishery in the Bredette segment of the Poplar River in relation to salinity, but some salinity degradations apparently do occur downstream in the river with reference to conditions in the upper segments of the two Poplar forks. As a result, both the suspended and the dissolved materials of the middle mainstem would tend to biotically degrade its waters to some extent, with suspended sediment possibly the more limiting of the two variables. But this degradation would be relatively minor, and assuming no other affecting factors, a good fishery might be expected, especially in view of the mainstem's high flow characteristics. However, the mid-Poplar's salinity characteristics could significantly detract from other water uses, such as municipal supply, as will be discussed elsewhere in this report.

Common constituents.

The middle reach of the Poplar River can be characterized as having a slightly saline, very hard (10, 19), and highly alkaline (high total alkalinity concentrations) type of sodium bicarbonate waters throughout the year (Table 52). As observed previously for DS-SC, ionic compositions in the Bredette segment of the river should also be generally similar to those obtained in the two upstream forks in view of the small volume of non-fork waters entering the river below Scobey. This was found to be the general case with ionic concentrations in the middle segment most commonly either closely equal to or intermediate to those in the lower Middle and East Forks. In many cases, the Middle Fork provided the low concentration of any parametric triumvirate involving the two forks and the middle Poplar River. An example of this mid-Poplar intermediacy is provided by the HCO_3/SO_4 ratios in Table 25 where ratios for the middle mainstem were typically located between those obtained for the two streams that join to form the main river. However, a major exception to this observation was found to reside in sodium with the middle reach concentrations of this variable tending to be somewhat higher than those observed in the two forks. This aspect, in turn, is paralleled by the generally higher %Na and SAR values and by the higher $Na/(Ca + Mg)$ ratios that were obtained in the middle mainstem over the tributary streams (excluding the West Fork). In addition, magnesium concentrations typically exceeded that of calcium in the middle segment, as observed for the East Poplar River, but this feature was more distinct in the larger stream than in its tributary with lower Ca/Mg ratios obtained in the first instance (Table 25).

Regardless of such slight chemical differences between the various Poplar sampling stations, ionic compositions and water qualities in the Poplar-Bredette reach were not that much different, for the most part, from that in the two upstream forks. In all cases, qualities were better in the spring season with its tendency towards higher flows. The better qualities of the March-May period were most noticeable when discharges were greater than 19.9 cfs, although the high turbidity-suspended sediment levels that are developed

Table 52. Summary of chemical analyses of water collected from the Poplar River near Bredette (middle reach, main river above the West Fork)--common constituents.

Stat	CO_2	HCO_3	CO_3	TA	PA	Cl	SO_4	Ca	Mg	TH	Na	SAR	%Na	K
November-February														
N.	4	4	4	4	0	4	4	4	4	4	4	4	4	4
Min	3.4	651	0.0	557	--	18.	330	37.	46.	280	290	7.3	65.	7.5
Max	40.	1240	14.	1020	--	37.	570	81.	86.	560	480	8.9	69.	13.
Mean	17.4	861	3.5	713	--	24.	405	53.8	58.8	378	350	7.9	66.5	9.8
Med	13.1	777	0.0	637	--	20.	360	48.5	51.5	335	315	7.7	66.	9.3
March-May (low flows)														
N.	1	3	3	3	0	3	3	3	3	3	5	3	1	1
Min	--	540	0.0	461	--	13.9	160	33.	40.0	259	54	5.2	--	--
Max	--	590	11.	480	--	16.	300	37.8	45.	270	250	6.7	--	--
Mean	--	568	4.7	472	--	15.	228	35.6	42.1	263	162	5.9	--	--
Med	3.8	575	3.	476	--	15.	225	35.9	41.3	260	193	5.7	66	8.2
March-May (high flows)														
N.	2	3	3	3	0	3	3	3	3	3	3	3	2	3
Min	4.2	65	0.0	53	--	9.0	11	27.3	2.9	80	4.0	0.2	60	5.9
Max	4.3	427	26.	360	--	22.	280	36.	37.	240	190.	5.3	62	9.2
Mean	4.25	294	8.7	254	--	15.	150	32.4	23.6	177	115.	3.3	61	7.2
Med	4.25	390	0.0	350	--	13.	160	34.	31.	210	150.	4.5	61	6.6
March-May (extreme high flows)														
N.														
Min														
Max						NO AVAILABLE DATA								
Mean														
Med														
June-October (low flows)														
N.	5	5	5	7	0	7	7	7	7	5	7	5	5	5
Min	1.7	385	5	400	--	8.5	210	22.	35.	230	180	5.1	61.	9.9
Max	2.9	650	123	580	--	19.	380	36.	57.8	270	320	8.6	72.	12.
Mean	2.3	547	41	527	--	14.5	316	29.2	48.3	258	275	7.2	67.8	10.6
Med	2.5	599	32	550	--	16.	310	29.	50.	260	282	7.3	68.	10.
June-October (high flows)														
N.	2	3	3	3	0	3	3	6	6	3	6	3	3	3
Min	1.2	359	0.0	294	--	5.3	140	17.6	23.	160	120	4.1	60	12.
Max	2.3	626	12.	531	--	14.	280	39.	60.5	278	444	6.7	66	16.
Mean	1.8	517	7.7	436	--	10.3	230	29.3	41.4	236	318	5.7	63	14.3
Med	1.8	565	11.	483	--	12.	270	27.7	42.8	270	324	6.4	63	15.

at this time would tend to detract from the better qualities that are established under such high flow regimes.

Like the other Poplar streams, sodium and bicarbonate were the dominant ionic components of the mid-Poplar samples with sulfate and calcium-magnesium representative of secondary ionic constituents (Table 52). Chloride and potassium (and fluoride) can again be viewed as insignificant ions in the waters, although chloride levels were slightly higher in the middle mainstem than in the Middle and East Forks. This latter feature coupled with the high sodium concentrations and the magnesium > calcium characteristics of the Bredette station would suggest that the non-fork waters are enriched in these three constituents relative to the major basin streams. Similar to potassium, carbonate and carbon dioxide were also largely nondistinctive in the river; however, comparatively high concentrations of the former variable and low levels of CO_2 were obtained under the high pH's of the biologically active summer season whereas high concentrations of the second parameter and indistinct levels of CO_3 were obtained under the low pH's and reducing conditions of the dormant winter period.

As observed for carbonate and carbon dioxide, the middle reach of the Poplar River also demonstrated various seasonal changes in ionic concentrations with respect to its major common constituents. The mid-Poplar appeared to be more sodium-magnesium sulfate in character during the summer and winter than during the spring while becoming more calcium bicarbonate in nature under the higher flows of the spring season. These changes are illustrated in Table 25 by the greater HCO_3/SO_4 and Ca/Mg ratios and by the lower $Na/(Ca + Mg)$ ratios that were obtained for the winter and summer seasons over those of the spring period. As might be expected, such chemical alterations in the Bredette mainstem coincide with the seasonal changes in water chemistry that have been described for the upstream forks of the river. Hydrologic and biotic relationships relative to these seasonal changes have been briefly alluded to previously in this report. For example, the distinctively low Ca/Mg ratios in the middle Poplar mainstem during the summer season are probably reflective of a biogenetic precipitation of calcium as $CaCO_3$ during this high pH, warm weather period. This would also account for the somewhat low total alkalinity and bicarbonate concentrations and for the relatively low HCO_3/SO_4 ratios that have been noted for the June through October months. Additional alterations in composition from the spring to the summer and from the winter to the spring are probably reflective of the differing chemistries between the baseline flow inputs to the Poplar versus that in waters that enter the stream under runoff conditions.

Nutrients and other constituents.

Dissolved iron concentrations were relatively low in the middle reach of the Poplar River (Table 53) and typically lower than the concentrations of iron in the Scobey segments of the upstream forks. This feature is in keeping with the general tendency for this constituent to decrease in a downstream direction in the Poplar Basin. Apparently the bulk of the iron in the Poplar waters arises in the basin's headwaters area with minor inputs of iron to the Poplar streams occurring in the lower portions of the drainage. As a result of this decline, iron levels in all of the samples collected from the Bredette reach were typically below those concentrations that are suggestive of adverse biotic effects, and they were typically below the level

Table 53. Summary of chemical analyses of water collected from the Poplar River near Bredette (middle reach, main river above the West Fork)--nutrients and other constituents.

Stat	TN	TK_jN	TON	NH_3N	NO_xN	TP	OP	COD	F	Si	D-B	D-Fe	T-Fe
November-February													
N.	4	4	4	4	4	4	4	0	4	4	4	4	0
Min	0.54	0.53	0.50	0.0	0.0	0.02	0.0	--	0.4	6.5	1.3	0.01	--
Max	0.89	0.74	0.73	0.03	0.16	0.05	0.04	--	0.8	15.	2.4	0.04	--
Mean	0.71	0.66	0.64	0.015	0.05	0.03	0.01	--	0.6	9.7	1.8	0.02	--
Med	0.70	0.68	0.67	0.015	0.02	0.03	0.0	--	0.6	8.6	1.7	0.02	--
March-May (low flows)													
N.	1	1	1	1	2	2	2	0	3	1	1	1	1
Min	--	--	--	--	0.01	0.01	0.01	--	0.4	--	--	--	--
Max	--	--	--	--	0.04	0.037	0.05	--	0.5	--	--	--	--
Mean	--	--	--	--	0.025	0.024	0.03	--	0.4	--	--	--	--
Med	0.50	0.46	0.46	0.0	0.025	0.024	0.03	--	0.4	5.4	1.3	0.02	0.63
March-May (high flows)													
N.	2	3	2	3	3	3	3	0	3	2	2	2	0
Min	0.51	0.49	0.46	0.02	0.01	0.02	0.0	--	0.1	3.6	0.7	0.04	--
Max	0.54	4.5	0.47	0.07	0.51	0.74	0.20	--	0.5	6.1	0.9	0.06	--
Mean	0.53	1.84	0.47	0.05	0.18	0.26	0.08	--	0.3	4.9	0.8	0.05	--
Med	0.53	0.53	0.47	0.07	0.02	0.02	0.04	--	0.4	4.9	0.8	0.05	--
March-May (extreme high flows)													
N.													
Min													
Max					NO AVAILABLE DATA								
Mean													
Med													
June-October (low flows)													
N.	5	7	5	7	7	7	6	0	5	5	5	5	2
Min	0.74	0.47	0.71	0.0	0.0	0.03	0.0	--	0.4	3.6	1.1	0.02	0.46
Max	0.98	1.0	0.96	0.01	0.03	0.11	0.01	--	0.6	6.8	1.9	0.03	0.70
Mean	0.87	0.83	0.86	<.01	0.01	0.07	<.01	--	0.5	5.8	1.5	0.02	0.58
Med	0.90	0.89	0.89	<.01	0.01	0.07	0.01	--	0.5	6.0	1.5	0.02	0.58
June-October (high flows)													
N.	2	3	2	3	3	3	3	0	3	2	2	2	4
Min	1.0	0.84	1.0	0.0	0.01	0.06	0.0	--	0.2	4.1	0.9	0.04	0.75
Max	1.9	1.7	1.6	0.06	0.19	0.41	0.06	--	0.3	6.5	1.5	0.07	1.2
Mean	1.45	1.18	1.30	0.04	0.07	0.21	0.03	--	0.3	5.3	1.2	0.055	0.90
Med	1.45	1.0	1.3	0.06	0.02	0.15	0.03	--	0.3	5.3	1.2	0.055	0.83

that defines a minimal iron risk (Table 15). In contrast to iron, boron and fluoride concentrations were essentially the same in the mid-Poplar reach as in the East and Middle Forks, but these constituents were also not at adequate levels to be suggestive of biotic degradations, although boron could be influential on other water uses from the river such as irrigation.

Mean and median silica concentrations in the mid-Poplar reach were slightly lower than those observed for the lower West and Middle Forks. In addition, concentrations in the middle mainstem were typically below the average for Montana's streams (12) and well below the median value of silica in the nation's surface waters (83). However, this constituent would not be viewed as a critical water quality parameter in the main river with concentrations well above the minimum levels that can be limiting to periphytic diatoms (80).

Seasonal changes in silica in the Bredette reach were quite similar to those described for the lower West Fork and quite different from that noted for the East Poplar River. That is, the distinct winter to summer decline in silica that was evident in the East Poplar was largely absent from both the Bredette reach and from the lower West Fork (and also from the lower Middle Fork). Only a slight summer depression in silica was evident in these three reaches, possibly as a result of enhanced diatom incorporation during this warm weather season; a slight decline in silica was also evident in the spring season (Table 53) probably in association with runoff dilutions as well as from biological utilization. As described for the West Fork, the relatively large volumes of water in the Bredette reach of the Poplar mainstem probably account for this dampening of the summer silica depression that was quite obvious in the upstream segments of the drainage with their smaller volumes of flow. However, the reduced nutrient concentrations of the more downstream segments of the Poplar drainage, e.g., the lower reach of the West Fork and the middle segment of the Poplar mainstem, with the associated losses in primary production, might also have played a role in this regard.

Such nutrient reductions in the downstream portions of the Poplar drainage are illustrated in Table 53 for the Bredette reach of the mainstem, and this feature was most pronounced in relation to the inorganic nitrogen species. Orthophosphate (OP) concentrations in the mid-Poplar were also generally nondistinct, as has been observed for other streams in the basin, but they did appear to be generally higher in this segment than in the major Poplar tributaries. In contrast, total phosphorous concentrations appeared to be somewhat lower in the mainstem than in the various forks, and as a result, mean and median TP levels at the Bredette station were typically below the lower reference criterion for phosphorous eutrophication in all of the seasons except for the summer period. Thus, waters in the middle reach of the Poplar River, unlike the upstream segments, were most likely phosphorous limited and non-eutrophic on this basis for a major part of the year.

Levels of TP at the Bredette sampling site tended to increase during the runoff periods, probably in response to inputs from overland flow, and TP also tended to increase to some extent from the winter to the summer season possibly because of a more pronounced incorporation of inorganic phosphorus into organic linkage during the latter months. Concentrations of the combined nitrogen species also became greater in the mid-Poplar in the summer

over the winter season, probably for the same reason, with a concomitant June-October decline in the inorganic nitrogen species, i.e., ammonia and nitrite-nitrate, possibly in conjunction with the enhanced biotic activities and nutrient uptakes of the warm weather period. However, combined nitrogen never achieved adequate levels at any time during the year to be suggestive of pollutive inputs to the stream. This observation is supported by the organic carbon analyses of middle reach samples (Table 54) where TOC concentrations were only slightly higher than the average for this variable in unpolluted, natural waters (87).

No consistent and distinct differences in the combined nitrogen species became evident among the various segments of the Poplar drainage. But as noted, ammonia and nitrite-nitrate were in distinctively low concentrations in the Bredette reach of the main Poplar River, even during the winter, probably as a result of upstream biotic utilizations in the face of a small downstream nutrient loading to the river. Inorganic nitrogen levels did tend to increase to some extent during the runoff periods in relation to the intensified inputs at this time from overland flow. However in no cases was ammonia at sufficient levels to point to biotic toxicities. In addition, only in rare instances were ammonia-N plus nitrite-nitrate-N at adequate concentrations to provide TIN levels in excess of the lower reference criterion for nitrogen eutrophication. In turn, the mean and median values of TIN were well below this reference level. Thus, the middle reach of the Poplar River can be graded as non-eutrophic at the present time with the river both nitrogen- and phosphorus-limited during the months of November to May, nitrogen-limited in the summer months of June to October, and probably more nitrogen-limited than phosphorus-limited throughout the year.

These nutrient features of the middle Poplar in comparison to the case for upper segments of the Poplar forks, particularly the East Poplar, indicate that a large proportion of the nitrogen concentrations in the Poplar drainage originate within the basin's headwaters area. As a result of the reduced nutrient inputs downstream in the drainage, about a 35-fold increase in ammonia-nitrogen plus nitrite-nitrate-nitrogen (TIN) would be required to afford eutrophic conditions during the critical warm weather months in the lower portions of the basin. In addition, about a 10-fold to 50-fold increase in ammonia at the pH levels of the Bredette reach, depending upon season, would be necessary to invoke toxic effects on the aquatic biota. On these bases, therefore, nitrogen does not appear to be as critical a water quality variable in the mid-Poplar River as has been noted for the upstream waters of the Poplar region.

Metals and miscellaneous constituents.

As described previously, dissolved iron was not at adequate levels in the mid-Poplar River to affect the stream's aquatic biota, regardless of the metal's generally high total recoverable concentrations (Table 53). As indicated in Table 54, this would also apply to most of the trace elements analyzed in samples from the river's middle reach. Such a listing would include those trace elements that have both their total recoverable and dissolved concentrations below the appropriate reference criteria in Table 15, i.e., As, B, Be, Cd, Cr, Cu, Ni, Pb, Se, and Zn. In addition, although Al and Mn (and Fe) had relatively high TR concentrations, these metals might also be added to this listing with dissolved concentrations well below the

Table 54. Summary of chemical analyses of water collected from the Poplar River near Bredette (middle reach, main river above the West Fork)--metals and miscellaneous constituents.

Stat	TOC	D-Al	T-Al	D-As	T-As	T-B	T-Ba	D-Be	T-Be
N.	2	5	6	5	6	7	1	5	2
Min	12	0.0	0.20	0.001	<.004	0.10	--	0.0	0.0
Max	16	0.02	1.0	0.003	<.025	3.4	--	0.01	<.01
Mean	14	0.01	0.553	0.002	<.014	1.65	--	0.002	<.005
Med	14	0.01	0.505	0.003	<.015	1.6	0.2	0.0	<.005

Stat	D-Cd	T-Cd	T-Co	D-Cr	T-Cr	D-Cu	T-Cu	D-Hg	T-Hg
N.	5	3	1	5	3	5	7	5	4
Min	0.0	<.001	--	0.0	<.05	0.0	0.004	0.0	0.0
Max	0.0	<.01	--	0.004	<.05	0.002	0.01	0.0028	0.0005
Mean	0.0	<.004	--	0.001	<.04	0.001	<.01	0.0006	<.0002
Med	0.0	0.001	<.01	0.0	<.05	0.001	<.01	0.0	<.0002

Stat	D-Li	T-Li	D-Mn	T-Mn	D-Mo	T-Mo	D-Ni	T-Ni
N.	5	2	5	4	5	2	5	2
Min	0.02	0.09	0.0	0.06	0.0	0.001	0.002	<.01
Max	0.12	0.11	0.03	0.19	0.003	<.10	0.004	<.05
Mean	0.08	0.10	0.01	0.12	0.0014	<.05	0.003	<.03
Med	0.07	0.10	0.01	0.11	0.001	<.05	0.004	<.03

Stat	D-Pb	T-Pb	D-Se	T-Se	T-Sr	D-V	T-V	D-Zn	T-Zn
N.	5	4	5	6	0	5	2	5	7
Min	0.0	<.05	0.0	0.0	--	0.0	<.10	0.0	<.005
Max	0.001	<.100	0.0	<.01	--	0.0029	<.11	0.01	0.04
Mean	0.0002	<.06	0.0	<.005	--	0.0007	<.105	0.006	<.012
Med	0.0	<.05	0.0	<.01	--	0.0001	<.105	0.01	<.01

corresponding reference levels. Ba and Co were also unsuggestive of water quality problems with the TR concentrations of these metals less than the dissolved values listed in Table 15. Similarly, Li, Mo, and V were non-distinctive with concentrations in the mid-Poplar samples well below the levels that are required to adversely affect aquatic organisms (41, 93). Many of these trace elements also had concentrations in all of the analyzed samples below their minimal risk levels (Table 15); this would include Al, As, B, Ba, Be, Cd, Cr, Cu, Pb, Se, and Zn, and this occurrence further indicates that these particular elements do not pose a water quality threat to the stream biota. Only Fe, Mn, and Ni were found in occasional samples with concentrations above the minimal risk levels, but concentrations were consistently below these metals' primary reference criteria. As a result of these features, only mercury of the nineteen constituents listed in Table 54 is suggestive of a water quality problem in the middle Poplar River at the present time.

As observed for several of the Poplar drainage stream segments, some samples were also collected from the middle mainstem with either the dissolved or TR concentrations of mercury above the grab sample criterion for this constituent. About 22% of the samples exceeded this reference value, and the mean dissolved concentration of mercury (Table 54) was greater than this element's average standard. In addition, between 22% and 44% of the samples had mercury in excess of hazardous levels. Such results would suggest that mercury is representative of at least an occasional water quality problem in the middle mainstem, and they also indicate that this constituent is possibly a more prevalent problem in the middle segment than in the upstream forks of the river since a higher detection success was obtained in the former case than in the smaller streams.

The major contribution of mercury to the basin's downstream waters appears to come from the Middle Fork, rather than from the East Poplar (compare Tables 27 and 43), and also from the intermediate input waters to the main river below Scobey. However, additional collections of this kind will have to be made to more precisely identify the magnitude of this difficulty in the middle river. The import of mercury as a water quality problem has been discussed previously in relation to the lower Middle Fork. The recommendation of the Environmental Protection Agency that " . . . little mercury can be added to the aquatic environment . . . (24)" appears to be particularly applicable to the mid-Poplar with respect to potential mercury additions to the drainage from the Coronach strip mining and electrical generation development in Saskatchewan, Canada.

Lower Reach Poplar River near Poplar

Flow characteristics.

The United States Geological Survey flow gaging and water quality sampling station on the lower reach of the Poplar River is located about 43 miles (69 kilometers) below the confluence of the West Fork and 11 miles (18 kilometers) above the mouth of the river near Poplar, Montana (94). The Poplar River Basin at this point has an effective drainage area of 2892 square miles versus effective areas of 1474 square miles and 3061 square miles at the Bredette site and at its mouth respectively (55). As a result of this station location on the lower river, the discharges that are moni-

tored at this Poplar site should be representative of almost all of the water that arises within the drainage (i.e., about 95%), with the quality data thereby representative of a composite of those qualities that are developed within most of the various surface waters and groundwaters of the region. As indicated in Table 55, an adequate number of samples had been collected from the Poplar River near Poplar to allow for a fairly complete seasonal-flow classification of this site's quality information.

Discharges in the lower reach of the Poplar River should be equal to the flows of the middle reach near Bredette plus those of the lower West Fork in addition to those waters that enter the main river below the confluence of the West Fork with the mainstem. As a result and as suggested in Table 55, flows in the lower Poplar were found to be relatively high in comparison to those that were obtained in the other segments of the drainage. Mean and median flows that were gaged for the Poplar station in conjunction with the quality collections were between 1.5-times and six-times higher than the flows of the Bredette reach, depending upon the season and statistic, and they were typically above ten cfs for a large part of the year. Average monthly values obtained by the USGS for the lower Poplar were also commonly above ten cfs, except for the month of January, with the mean yearly discharge of the Poplar station (92,560 acre feet) nearly two-times greater than that of the Bredette location on the middle reach (55). About 80% of the total annual discharge in the Poplar Basin occurred under the runoff conditions of the spring season when mean monthly flows in the river typically ranged between 128 cfs and 705 cfs (55). During the summer and winter periods, flows in the lower Poplar averaged 51 cfs and 13 cfs respectively. Thus, the Poplar River in its lower reach makes a much closer approach to the conceptual picture of a "true" river on the basis of stream discharge than the case for its upstream reaches such as the East Poplar River. Even under an extreme low flow regime the mean monthly flows of the lower Poplar would be greater than two cfs through all of the seasons except for the winter period when they would average about 0.6 cfs (55). As a result, flow does not appear to be as critical a variable in relation to the Poplar's fishery in this lower segment as has been described previously for several of the smaller, upstream reaches.

Due to the almost two-fold greater yearly discharge in the lower Poplar over the middle segment, the low and high flow classes that were established for this particular downstream station, by which to initiate the water quality data separations, had to be expanded by two-times over those classes employed in relation to the upstream sampling sites. These lower river, flow-class values have been defined previously. Using the daily flow data that are available for the Poplar station for water years 1964 to 1974 (94), the percentage of days in each season falling into each of the six flow classes were determined as follows: November to February--32.9%, March to May (low flows)--7.1%, March to May (high flows)--11.0%, March to May (extreme high flows)--7.1%, June to October (low flows)--33.0%, and June to October (high flows)--8.9%. These percentages differ to some extent with respect to those calculated for the upstream stations through the higher number of days in the lower reach having high flow characteristics for the March to October seasons. However, of the days included in the winter period, only 1.5% had flows in excess of the upper criterion for the low flow classification, and no quality samples were collected in the

Table 55. Summary of chemical analyses of water collected from the Poplar River near Poplar (lower reach main river below the West Fork)--field parameters and dissolved solids.

Stat	Flow	Temp	pH	Clr	Turb	TSS	SC	DS	DO--%Sat		BOD	TC	FC
November-February													
N.	5	5	5	0	5	0	5	5	5	5	0	1	2
Min	6.6	0.0	7.8	--	2.	--	1520	965	9.2	68	--	--	2
Max	29.	0.5	8.7	--	9.	--	2530	1500	13.2	98	--	--	4
Mean	17.7	0.1	8.16	--	4.6	--	2028	1287	11.9	88	--	--	3
Med	19.	0.0	8.1	--	4.	--	2050	1280	12.2	90	--	120	3
March-May (low flows)													
N.	3	4	4	0	4	2	4	4	2	2	0	2	2
Min	20.E	0.0	8.0	--	7.	22.9	980	620	6.6	49	--	4	0
Max	37.	21.0	8.53	--	15.	55.	1560	1000	9.4	113	--	87	160
Mean	28.7	12.6	8.36	--	10.8	39.0	1238	883	8.0	81	--	46	80
Med	29.	14.6	8.46	--	10.5	39.0	1205	955	8.0	81	--	46	80
March-May (high flows)													
N.	3	5	5	0	2	1	5	5	5	2	0	2	2
Min	45	4.0	7.9	--	20.	--	1020	684	8.0	103	--	10	18
Max	158	19.0	8.5	--	30.	--	1420	902	12.6	110	--	72	60
Mean	109	14.2	8.26	--	25.0	--	1188	767	9.5	107	--	41	39
Med	125E	16.5	8.2	--	25.	12	1100	759E	8.9	107	--	41	39
March-May (extreme high flows)													
N.	2	2	2	0	2	1	2	2	2	1	1	1	1
Min	250E	0.1	7.96	--	9.	--	590	356	8.9	--	--	--	--
Max	444	11.0	8.2	--	35.	--	947	772	9.3	--	--	--	--
Mean	347	5.6	8.08	--	22.0	--	769	564	9.1	--	--	--	--
Med	347	5.6	8.08	--	22.	9.4	769	564	9.1	87	3.4	4	4
June-October (low flows)													
N.	10	16	14	0	10	9	16	16	14	6	4	1	5
Min	5.E	11.5	8.5	--	3.	18.	1420	963	5.1	86	1.1	--	20
Max	37.	28.0	9.3	--	43.	62.	3180	1870	10.4	108	1.9	--	<100
Mean	20.3	19.6	8.76	--	18.7	29.9	1743	1153	8.1	96	1.6	--	<53
Med	20.5	19.8	8.75	--	11.5	25.8	1625	1100	8.3	97	1.7	34	49
June-October (high flows)													
N.	5	6	6	0	5	1	6	6	4	4	0	1	2
Min	53	20.0	8.37	--	15.	--	841	594	7.0	85	--	--	99
Max	478	25.0	8.8	--	95.	--	1550	1144	7.8	93	--	--	430
Mean	202	22.1	8.63	--	53.2	--	1176	834	7.3	90	--	--	265
Med	200	21.5	8.65	--	50.	72	1179	784	7.3	91	--	230	265

November to February months with flows in excess of 39.9 cfs (Table 55).

The above listed percentages can be utilized to establish yearly weighted mean and median values for pertinent water quality parameters in the lower Poplar as has been done previously for the other Poplar drainage stations. These calculated statistics, in turn, should provide some insight into the overall biotic effects of such parameters on the aquatic biota residing within the lower segment of the Poplar River.

As indicated in Table 56, the upper portion of the Poplar River Basin above the Bredette station on the middle reach contributes about 51% of the total yearly discharge in the region whereas the West Fork drainage and the intermediate inputs to the main river below this tributary's confluence contribute about 49%. These factors remain fairly constant regardless of the type of water year, although the upper reaches provide a slightly higher percentage when the basin is experiencing high flow conditions.

Quite distinctive in the Poplar Basin are the wide variations in annual flow from year to year. A typical discharge near 36,600 acre feet per year (AFY) occurs during the low flow periods whereas a value near 217,100 AFY is common for the high flow years (Table 56). Extremes in the drainage range from a low of 14,412 AFY during the "dust bowl" era of the early 1930's, with a yearly discharge of only 27,264 AFY obtained as recently as 1973, to a high of 332,937 AFY in 1952; a value of 195,726 AFY was measured in 1974 (55). These numbers provide a maximum 23-fold change in annual basin discharge for the 44-year period of record and a distinctive seven-fold difference in terms of a successive two year span (1973 and 1974). Such wide variations in stream flow might be expected in prairie systems such as the Poplar drainage which lack an obvious mountainous area, and due to these variations, water planning in these prairie regions would appear to be somewhat tenuous. As an added example, flow fluctuations on the basis of five year periods are also quite pronounced in the Poplar region. Average yearly flows in the drainage for any consecutive five years were as low as 36,853 AFY (1931-1935) and 56,057 AFY (1961-1965), and they were as high as 196,896 AFY and 126,125 AFY for the 1951-1955 and the 1967-1971 periods respectively. In addition to reducing planning effectiveness, such wide flow alterations might also have some adverse effects on the aquatic biota that would otherwise be largely absent from those drainages that provide for more constant and predictable discharge features. For the Poplar Basin, such flow-related and negative biotic influences would be most distinct in an upstream direction and much less definite near the mouth of the system.

Table 56 indicates that the three forks of the Poplar mainstem contribute closely similar annual flows to the downstream reaches in the following southwest to northeast sequence: West Fork > Middle Fork > East Poplar River. The West Fork contribution is 4% to 7% higher than that of the East Poplar, depending upon the type of water year, whereas that of the Middle Fork is only 3% to 4% greater than the provisions originating from the eastern tributary. All three of the forks provide between 63% and 78% of the yearly discharge in the main Poplar near its mouth, and the proportional contributions of the three forks to total basin flows are also dependent upon water year. The forks made their largest percent contributions during low water years even though a five-fold greater flow is common in these streams under high water conditions. Thus, these tributaries would appear

Table 56. Annual discharge contributions by type of water year of various water sources in the Poplar River Basin to the total yearly flow of the Poplar River near its mouth (in acre feet per year); associated percentages are also listed. Data taken from the Poplar River Task Force (1976c).

Sources	Low Water Year (b)			High Water Year (c)		
East Poplar-IB (a)	5,391(15%)			26,638(12%)		
Intermediate Inputs	2,871(8%)			12,798(6%)		
East Poplar-Scobey		8,265(23%)			39,436(18%)	
Middle Fork-IB	5,552(15%)			28,479(13%)		
Intermediate Inputs	3,642(10%)			18,158(8%)		
Middle Fork-Scobey		9,194(25%)			46,637(21%)	
Intermediate Inputs	1,141(3%)	1,141(3%)		25,774(12%)	25,774(12%)	
Main Poplar-Bredette			18,600(51%)			111,847(52%)
West Fork-IB	1,005(3%)			10,139(5%)		
Intermediate Inputs	9,614(26%)			44,570(21%)		
West Fork-Bredette		10,619(29%)	10,619(29%)		54,709(25%)	54,709(25%)
Intermediate Inputs	7,372(20%)	7,372(20%)	7,372(20%)	50,540(23%)	50,540(23%)	50,540(23%)
Main Poplar-Poplar	36,591(100%)	36,591(100%)	36,591(100%)	217,096(100%)	217,096(99%)	217,096(100%)

Sources	Intermediate Water Year (d)			Average Water Year (e)		
East Poplar-IB (a)	11,412(15%)			12,475(13%)		
Intermediate Inputs	6,815(9%)			6,700(7%)		
East Poplar-Scobey		18,227(23%)			19,175(21%)	
Middle Fork-IB	11,535(15%)			12,961(14%)		
Intermediate Inputs	7,626(10%)			8,422(9%)		
Middle Fork-Scobey		19,161(24%)			21,383(23%)	
Intermediate Inputs	2,850(4%)	2,850(4%)		6,951(8%)	6,951(8%)	
Main Poplar-Bredette			40,238(51%)			47,509(51%)
West Fork-IB	3,042(4%)			3,799(4%)		
Intermediate Inputs	18,151(23%)			20,645(22%)		
West Fork-Bredette		21,193(27%)	21,193(27%)		24,444(26%)	24,444(26%)
Intermediate Inputs	17,016(22%)	17,016(22%)	17,016(22%)	20,607(22%)	20,607(22%)	20,607(22%)
Main Poplar-Poplar	78,447(102%)	78,447(100%)	78,447(100%)	92,560(99%)	92,560(100%)	92,560(99%)

(a) IB--international boundary. (b) Yearly discharge means of years with annual flows less than 50,000 acre feet per year, N.=15. (c) Yearly discharge means of years with annual flows greater than 142,000 acre feet per year, N.=9. (d) Yearly discharge means of years with annual flows between 50,000 and 142,000 acre feet per year, N.=20. Yearly discharge means of all years, N.=44.

to have their greatest significance to basin discharge during low flow periods. In contrast, various non-fork inflows to the mainstem below Scobey make their highest proportional contribution to basin flows during high water years, and this feature is most obvious in relation to the intermediate inputs of water to the middle, Bredette reach (Table 56). That is, during low flow years, these intermediate, middle reach inputs are largely insignificant, i.e., at 3%, versus the 12% value that is obtained when the basin possesses higher water volumes.

Between 30% and 33% of the water in the Poplar drainage arises in Canada and enters Montana via the major forks, and 12% to 15% of these waters originate in the East Poplar system. As a result of these small East Poplar percentages, flow reductions in the eastern fork because of activities associated with the Coronach development would be expected to have relatively minor effects on the yearly discharge of the lower river near its mouth. That is, a 50% reduction in the flows of the upper East Poplar would produce only a 6% to 8% decline in the discharge of the mainstem near Poplar. Such percentages also suggest that there is a distinct opportunity in the basin for diluting from various sources those water quality impacts that are developed in association with the Coronach development before the impacted waters derived from the East Poplar arrive in the lower portions of the drainage. However, the percentage contribution of water via the East Poplar is considerably higher in an upstream direction along the mainstem than at the Poplar's mouth, i.e., above Bredette, and it is also more distinct under low flow instead of high flow conditions. In addition, these percentages also vary by season with the more pronounced effects of East Poplar dewatering occurring in the late summer, fall, and winter months over the spring and early summer periods. Thus, the downstream dilution capacities of the Poplar drainage in Montana, and the extent of the downstream quality impacts, would also be expected to change to some degree in response to these three factors.

The seasonal variations in the East Poplar's comparative contributions to downstream flows are due to the fact that the flows of the eastern fork are much less variable and more uniform than those in the other tributaries. Also, higher flows are obtained in the former stream over the Middle and West Forks through the July to February period even though the yearly flows of the latter two streams are higher than that of the East Poplar (55). These aspects, in turn, are probably related at least in part to the regulatory and water-use effects of those impoundments that are now in operation in the East Poplar segment of the Poplar Basin, e.g., the Coronach town reservoir discussed previously and Clark's Bridge Dam on the extreme upper reach of the tributary near Hart, Saskatchewan (Figure 1).

Field parameters and dissolved solids.

Levels of suspended sediment and turbidity in the Poplar River for the various seasons did not demonstrate any marked or consistent changes from the Bredette station on the middle reach (Table 51) to the lower segment near Poplar (Table 55), nor were the levels of these variables in the lower reach distinctively higher than those in the lower portions of the upstream forks. Thus, the seasonal data that are available for turbidity-suspended sediment are not indicative of any substantial downstream increases in suspended materials from the headwaters of the Poplar Basin to its mouth. Al-

though turbidity-suspended sediment did tend to increase to some extent from the low flow to the high flow periods of the lower Poplar (Table 55), the maximum concentrations and runoff levels of these parameters were inadequate to be suggestive of fishery and aesthetic degradations in the lower reach. The yearly weighted mean and median levels of turbidity (14.6 JTU and 17.5 JTU respectively) point to the occurrence of a "good" fishery in the lower river relative to the European Inland Fisheries Advisory Commission (1965) grading system for suspended sediment. However, these yearly statistics are also suggestive of an overall increase in this variable (and suspended sediment) on the order of two-times from the upstream forks to the Poplar station, producing a slight downstream degradation of the stream's fishery on this basis as observed for the Bredette segment. That is, the fishery declines from the "excellent" designation assigned to several of the upstream waters to the "good" classification noted for the lower and middle segments as a result of the greater downstream sediment loads. But for the most part, turbidity and suspended sediment do not appear to be representative of major problem variables in the lower Poplar River. About a five- to six-fold overall increase in the stream's suspended material concentrations would be required to alter the lower Poplar's current fishery classification to a "poor" designation.

Quite distinctive in the lower Poplar is an absence of the noticeably high turbidity-suspended sediment levels (Table 55) that were obtained in occasional runoff samples from the middle Poplar near Bredette, e.g., 1100 JTU and 780 mg/l (Table 51), and also from the lower Middle Fork (Table 39). This absence might suggest that these high suspended sediment concentrations were dropped-out before the river waters reached the lower Poplar station; but a likely alternative is the case that these high levels were not picked-up in the lower reach due simply to happenstance and sampling schedules and to the small number of quality samples that had been collected for the turbidity-sediment analyses. Additional sampling at the Poplar site might also eventually show the occurrence of distinctively high levels of turbidity and suspended sediment in the lower river reach at times during the runoff periods, and the development of this feature would then act to degrade this water's fishery to some small degree as has been noted for the middle segment. But in any event, the turbidity-suspended sediment data that have been collected from the Poplar drainage and the lower Poplar River would indicate that such extremely high levels of these variables are a relatively rare and sporadic occurrence in the region and of a short duration once they are in effect; if this were not the case, much greater detection frequencies of high variable concentrations would be anticipated for the streams than what has been actually shown up to time of the data summaries in Tables 51 and 55.

Similar to the other Poplar drainage sampling sites, DS-SC levels at the lower Poplar station (Table 55) also demonstrated an inverse relationship with flow with the waters in this lower reach showing a better quality and a non-saline nature during the runoff periods while being of a worse quality and slightly saline under the low flow regimes. Like the East Poplar River, levels of DS-SC during the summer high flow stages were somewhat higher than what might be expected on the basis of discharge at this time, and this indicates that these particular waters were derived from different sources than the high flow waters that are developed during the spring season. On a seasonal basis, DS-SC levels in the lower Poplar River were gen-

erally higher than those in the Bredette reach (Table 51) which is keeping with the tendency for these parameters to increase to some extent in a downstream direction through the Poplar drainage. However, this middle segment to lower reach increase in DS-SC was largely absent on an annual basis with the yearly weighted mean and median statistics for these variables in the lower reach, i.e., 1065 mg/l and 1045 mg/l, and 1620 umhos and 1577 umhos respectively, quite similar to the values calculated for the middle Poplar, showing an average difference of less than one percent.

The lack of yearly change in dissolved solids from the Bredette station to the Poplar site in contrast to the seasonal increases downstream is probably due to the comparatively high percentage of days in the lower river having high flows and low dissolved solids concentrations relative to the case for the upper river locations, e.g., 18.1% of the spring days for the Poplar near Poplar versus a value of 7.6% for the East Poplar at the IB. But given the relatively low DS-SC levels of the lower West Fork and its high flows and associated dilution capacities described previously, this lack of change in dissolved materials between the middle and lower stream segments is still suggestive of some salinity loadings to the mainstem from the intermediate input waters to the river below the Bredette station. Using the yearly weighted median DS values established for the Bredette and Poplar stations and for the lower West Fork, plus the average annual flows of these three sites (55), the annual DS composite for these accessory waters below Bredette was calculated at 1435 mg/l. This estimated concentration is 12% lower than the value calculated for the intermediate waters entering the mainstem between Scobey and Bredette, and it is about 1.4-times higher than the weighted median DS level of the main river. Apparently the potential dilutions from the West Fork exactly counter these lower reach salinity loadings so that no overall, downstream increases of salinity become evident in the Poplar mainstem per se. However, the yearly weighted mean and median DS-SC statistics for the lower river are suggestive of a 1.15-fold to 1.53-fold annual downstream increase in salinity from the basin's headwaters area in Canada to the Poplar's mouth at the Missouri River in Montana. This increase factor varies to a considerable degree in response to variations in the statistics and parameters being used, and also in response to the particular headwaters stream that is being considered in the calculations.

With reference to Table 16, the yearly weighted mean and median values for DS-SC in the lower Poplar are indicative of a "good" fishery in this particular segment. In contrast, the upper East Poplar River can be graded as having a "generally excellent" fishery on this basis, but one that is marginal in this regard as a result of the stream's somewhat high salinity levels. Thus, the East Poplar appears to be prone to salinity degradations as evidenced by the reduced, "good to fair" fishery rating given to its downstream, Scobey reach. Such degradations also became evident in the Poplar mainstem in relation to its "good" rather than "excellent" fishery designation and in its higher DS-SC levels. However, about a three-fold increase in mainstem DS-SC levels would be required to further degrade this fishery to a "poor" classification with about a 1.3-fold increase required to produce a "fair" biotic rating. Given the large quantities of input, dilution waters entering the system below the IB north of Scobey (Figure 1), it would appear unlikely that the Coronach development can generate the necessary salinity impacts via the East Poplar to degrade the lower mainstem to this extent. That is, median DS concentrations in the upper East Poplar, coin-

cidental with a 50% reduction in flows, would have to be increased on the order of 35-times (to a level of 31,000 mg/l) in order to increase lower mainstem salinities to 3000 mg/l. A 6.5-fold increase in the East Poplar's DS would be necessary to degrade the lower mainstem's fishery to even a "fair" classification. Such marked increases in salinity in the eastern fork, regardless of the cause, would seem to be highly improbable.

The above described features indicate that water quality impacts arising in the upper East Poplar as a result of the Coronach development should be ameliorated to a large degree before they reach the mouth of the mainstem as a result of the large volumes of water entering the main river in Montana. For example, increases in salinity in East Poplar in excess of two-times will be required to produce relatively small DS increases in the lower mainstem in the vicinity of 10 mg/l. However, impact effects in the East Poplar River per se and in the middle reach of the main river will be much more pronounced than those in the lower river, and these potential water quality problems should pose the major basis of concern for the Poplar drainage relative to the Coronach facilities.

Organic-municipal pollution does not appear to be a problem in the lower Poplar drainage in view of the low BOD_5 and coliform concentrations that were obtained from the stream (Table 55). The few BOD_5 readings that have been taken from the river were consistently below those levels that might produce stream deoxygenations, i.e., about 5 mg/l for sluggish streams (41), and coliform concentrations were typically below Montana's criteria for these variables (Table 7). The only exception for fecal coliforms was obtained during a high flow period when the enhanced stream coliform levels at this time were probably related to inputs from overland flow off agricultural lands. As a result, only 7% of the samples from the lower Poplar would be expected to have fecal coliforms in excess of the State standard (44).

In association with this absence of organic pollution, dissolved oxygen concentrations were consistently high in the lower river, even during the winter season, with the yearly weighted mean and median %Sat values at 92% and 93% for the Poplar station. Montana's more stringent $B\text{-}D_1$ criterion for DO at 7.0 mg/l (44) was violated only in rare instances, in 13% of the samples, and primarily during the warm weather period, and this indicates that the lower Poplar is suitable for all types of fisheries on this one particular basis. However, temperature and pH are probably restrictive and the limiting parameters in this regard.

As indicated in Table 55, a marked winter depression in DO and %Sat was not evident in the lower Poplar River. Such a cold weather depression was quite distinct in many of the extreme upstream segments of the basin, and its absence from the lower reach culminates a general trend for this winter decline in DO to become less obvious in a downstream direction through the basin. This particular change in basin characteristics is possibly related to the downstream changes in stream morphometry from their alternating pool-riffle nature in the headwaters area to the more consistently channelized form of the lower reaches. With this change in morphometry, water retention times in the winter would be lower downstream than in the pool-riffle segments, and this would allow for a shorter period of time in the channelized segments per volume of water for the stream's aerobic processes to utilize the available DO in the face of an impeded re-aeration capacity as a result of overhead

ice-cover. In addition, the more channelized type of morphometry should provide added opportunities for open areas to develop in the ice-cover in association with the greater riffled stretches of stream, which would, in turn, afford a greater penchant for the re-oxygenation of waters in the lower river than would be the case for the ponded, upstream reaches. Because of these various features, dissolved oxygen does not appear to be a critical water quality variable in the lower Poplar in view of the low winter concentrations that have been noted for several of the upper drainage segments. In no cases were the reproductive requirements of sport fish (59) and the State's $B\text{-}D_3$ criteria for DO (44) violated by samples from the lower river, and in no instances were the low levels of DO that are suggestive of forced fish emigrations and secondary tastes and odors, i.e., between 2.5 mg/l and 3.0 mg/l (59), achieved in this lower portion of the Poplar Basin.

Regardless of these high DO concentrations, temperature and pH would probably act to delimit the lower Poplar as a cold water fishery. But similar to the upper Poplar segments, this limitation would not be due to the minimum values of pH since low pH's were also uncritical in the lower reach. More importantly, although levels of pH were relatively low and unimportant under the reducing and biologically dormant conditions of the cold weather season, a marked increase in this variable did become evident during the biologically active summer period possibly as a result of the enhanced photosynthetic utilization of bicarbonate ions at this time, and herein lies the crux of the pH-related problems that are developed in the lower river. Because of this increase, pH's were typically above the State's cold water reference criterion for this parameter (44) during the warm weather months, and also on occasion during the spring season, and sporadic samples were collected from the lower river with pH in excess of the maximum levels deemed desirable for a good fishing water (88). On this basis, therefore, the lower Poplar is best classified as either a $B\text{-}D_2$ or $B\text{-}D_3$ stream since only 3% of the collections from the Poplar station had pH values in excess of the reference criteria for these types of marginal or warm water streams. However, about 28% of the lower mainstem samples, all collected during the June-October period, did have pH's in excess of the upper limit for waters that can be classified as having a good freshwater fishery (88). Runoff events tended to reduce the pH of the lower river and thereby upgrade its fishery capacities at these times, and this was quite distinct during the spring season as a result of significant dilutions from the low pH and ionically impoverished snowmelt waters that enter the basin's streams during these months.

Like pH, grab sample temperatures also increased seasonally to a considerable degree in the lower Poplar River (Table 55), ranging from the values that were at or near freezing during the winter period to the much higher levels commonly in excess of 20 C that were obtained during the summer season. Such increases provided a maximum temperature swing in the river approaching thirty degrees Celsius (86 Fahrenheit) while averaging about twenty degrees (Celsius) through time spans of approximately 110 and 130 days from the spring to the summer and from the summer to the fall respectively. Low winter temperatures with values typically less than 1.5 C occurred in the lower river from about mid-November to the end of March (approximately 135 days). However, these low temperatures are probably not critical in relation to most kinds of fish, e.g., the cold water forms, although they might affect a few of the warm water varieties that have their lower temperature tolerances near this range, e.g., adult white sucker (2.5 C), juvenile emerald shiner (1.6 C),

adult yellow perch (3.7 C), and the fathead minnow (1.5 C) (85). Thus, the warm water species that are relatively sensitive to the cold would not be expected to develop extensive resident populations in the Poplar drainage in lieu of those warm water species that are more tolerant of near freezing temperatures such as the channel catfish (0.0 C) (85), for example, and probably northern pike and walleye (24). In contrast, the high summer temperatures of the lower river, being well below the upper tolerance limits for warm water species (79, 85, 92), would not be expected to have obvious effects on these types of fish while largely eliminating the cold water forms from the stream.

As indicated in Table 57, almost 50% of the quality samples collected from the lower Poplar had the associated temperatures in excess of the reference criteria for $B\text{-}D_1$, cold water streams. Median (and mean, Table 55), grab sample summer temperatures from the Poplar station, in contrast to those for the upstream drainage stations, were also in excess of this reference value. In addition, several of the summer temperature readings taken from the lower river were found to be in excess of the upper tolerance limits for three of the salmonid, cold water species that are common to Montana (brook, brown, and rainbow trout) (78, 82, 84). In contrast, the mean and median summer temperatures as well as 91% of the warm weather values were below the reference criterion for $B\text{-}D_3$ waters (Table 57). These various features would suggest that the lower Poplar River is probably warm water rather than cold water in character, and more warm water in character than the upstream segments in view of the greater mean and median summer temperatures in the lower river. Thus, although the State of Montana has classified the entire Poplar drainage as having marginal, $B\text{-}D_2$ waters (44), which may be applicable to several of the upstream segments with their lower overall temperatures, the lower reach of the Poplar is probably best described as a $B\text{-}D_3$ stream in relation to the relatively high summer temperatures that were obtained from this particular stretch of the river.

The salinity, suspended sediment, coliform, oxygen, and flow characteristics of the lower Poplar River are suggestive of an aesthetically pleasing and good fishing water that is not affected by pollutive inputs to any significant degree. But the high summer values of pH would tend to degrade this fishery to some extent, and both pH and temperature during the warm weather season would appear to restrict the development of a non-marginal, cold water fishery. As just described, the high summer temperatures of the lower river, in turn, apparently further delimits this reach into being a non-cold water, but a relatively good warm water stream. However, the results from various fishery surveys being conducted in the basin (50, 69, 70) will have to be eventually reviewed in order to definitely document the cold water-warm water nature of the Poplar streams as well as their overall piscatory qualities.

Common constituents.

In correspondence to the seasonal changes in DS-SC, common constituent concentrations in the lower Poplar River were also inversely related to flow (Table 58); relatively high concentrations were obtained during the summer and winter seasons but with lower levels typically observed during the spring period and particularly in conjunction with runoff events. Total hardness provides an example of these seasonal alterations where very hard-extremely hard (and slightly saline) waters were commonly obtained under low flow con-

Table 57. Grab sample temperature characteristics of the lower Poplar River near Poplar for the period of May 6, 1949 to August 22, 1977 expressed as the percentage of readings falling within various temperature ranges specified for cold water (19.4 C) and warm water (26.7 C) fisheries; minimum, maximum, and median values are also listed. Data were taken from Aagaard (1969) and from other sources.

Temperature Range or Statistic	Winter November-February	Runoff March-May	Warm Weather June-October
<19.4C	100%	96%	42%
19.4C to 26.7C	0%	4%	49%
>26.7C	0%	0%	9%
Minimum	0.0C	0.0C	2.2C
Maximum	3.7C	23.9C	30.0C
Median	0.0C	8.9C	20.0C
Sample Number	33	67	69

ditions (<40 cfs) while less hard (and non-saline) waters were more characteristic of the spring and high flow collections. But in contrast to the downstream increases in DS-SC that were obtained on a seasonal basis between Bredette and Poplar, many of the common ions actually demonstrated a downstream decline in most seasons between these two mainstem stations. Such a decline might be expected given the dilution capacities of the West Fork with its comparatively low ionic concentrations. This downstream decrease in ionic levels was quite distinct for sulfate which had low concentrations in the West Fork, but it was less obvious for bicarbonate and for certain of the other ions, and a few of the constituents, e.g., sodium and chloride, did afford exceptions to this observation. In essence, many of the ionic components typically demonstrated an intermediate concentration at the Poplar site between those obtained for the main river Bredette station and those analyzed for the lower West Fork reach. Such ions would include bicarbonate, sulfate, calcium, and magnesium.

The intermediate nature of the lower Poplar chemistries relative to the Bredette and lower West Fork analyses are further illustrated in Table 25 wherein the ionic concentration ratios of the Poplar station are found to reside between the corresponding ratios calculated for the middle mainstem samples and those established for the West Fork-FBB collections. As a result, the seasonal changes in these ratios for the lower Poplar, e.g., the summer decline in Ca/Mg, the winter to spring increase in Na/(Ca + Mg), and the spring to summer increase in HCO_3/SO_4, are best described as being an almalgamation of the changes in these ratios that have been described previously for the middle Poplar and for the lower West Fork. On these bases, therefore, the West Fork would appear to have a significant influence on the chemistry of the Poplar River below its confluence as well as an effect on the lower segment's salinity characteristics.

Table 58. Summary of chemical analyses of water collected from the Poplar River near Poplar (lower reach main river below the West Fork)--common constituents.

Stat	CO_2	HCO_3	CO_3	TA	PA	Cl	SO_4	Ca	Mg	TH	Na	SAR	%Na	K
November-February														
N.	4	5	5	5	0	5	5	5	5	5	5	5	5	5
Min	2.0	587	0.0	506	--	48	250	31.	36.	230	280	8.1	66.	7.4
Max	18.	806	15.	661	--	290	310	74.	56.	420	420	9.5	72.	8.1
Mean	10.4	729	3.0	603	--	162	284	53.6	48.0	334	358	8.6	69.6	7.8
Med	10.	772	0.0	633	--	120	290	53.	50.	330	370	8.1	71.	7.8
March-May (low flows)														
N.	2	4	4	4	0	4	4	4	4	4	4	4	2	2
Min	2.8	439	0.0	360	--	8.8	130	26.9	23.	162	160	5.2	64.	7.7
Max	7.0	560	13.	460	--	110.	240	35.	32.	200	300	9.2	76.	10.
Mean	4.9	497	6.3	418	--	50.	170	30.3	26.5	184	221	7.1	70.0	8.9
Med	4.9	494	6.	426	--	40.	156	29.6	25.5	186	212	7.0	70.	8.9
March-May (high flows)														
N.	2	2	2	2	0	2	2	2	2	2	4	2	2	2
Min	2.0	388	6.	330	--	81	140	27.	21.	150	53	8.4	75.	5.4
Max	2.8	520	13.	450	--	150	210	30.	28.	190	270	8.5	76.	6.9
Mean	2.4	454	9.5	390	--	116	175	28.5	24.5	170	156	8.5	75.5	6.2
Med	2.4	454	9.5	390	--	116	175	28.5	24.5	170	151	8.5	75.5	6.2
March-May (extreme high flows)														
N.	1	2	2	2	0	2	2	2	2	2	2	2	1	2
Min	--	271	0.0	222	--	8.2	73	26.	16.	130	79	3.0	--	8.2
Max	--	434	0.0	356	--	11.	122	32.4	21.4	169	145	4.9	--	8.3
Mean	--	353	0.0	289	--	9.6	98	29.2	18.7	150	112	4.0	--	8.25
Med	2.7	353	0.0	289	--	9.6	98	29.2	18.7	150	112	4.0	55	8.25
June-October (low flows)														
N.	6	7	7	10	0	10	10	16	16	7	16	7	6	6
Min	0.5	534	11	468	--	0.1	240	17.0	30.	166	280	8.3	73.	9.2
Max	2.5	635	32	549	--	590	311	28.4	48.	260	600	16.	83.	14.
Mean	1.7	580	21	516	--	128	277	25.0	39.5	217	339	10.7	76.5	11.4
Med	1.8	580	21	518	--	81	281	25.3	39.8	220	321	9.7	74.5	11.
June-October (high flows)														
N.	4	6	6	6	0	6	6	6	6	6	6	6	4	5
Min	1.1	370	0.0	308	--	9.6	120	20.	20.5	144	130	4.6	63.	8.9
Max	2.9	540	24.	480	--	215.	260	31.	38.	230	290	8.3	72.	12.
Mean	1.7	458	11.5	396	--	63.	192	27.1	28.4	186	204	5.5	67.8	10.3
Med	1.9	448	11.	387	--	26.5	187	27.8	27.5	190	198	6.6	68.	10.

As noted previously, sodium and chloride provided exceptions to the intermediate nature of ionic concentrations in the lower Poplar samples in showing an increase in levels from the Bredette to the Poplar stations in all seasons. The tendency for chloride to increase downstream in the drainage has been also observed to some extent at the Bredette station, but mean and median chloride concentrations were much more distinctively high in the lower segment than in the middle reach in relation to those that have been obtained for the upstream sampling stations above Bredette, i.e., between six- and 66-times higher depending upon the season, sampling station, and statistic. The marked downstream increases of sodium and chloride in the Poplar mainstem, regardless of the declines in the other ions, probably accounts for the slight seasonal enhancements in DS-SC that were obtained for the Poplar River from the Bredette to the Poplar locations. These increases in sodium and chloride, and DS-SC, are probably a reflection of the influence of intermediate inputs to the lower Poplar, and such inflow waters would be expected to have relatively high concentrations of these two constituents.

The statistical ionic concentrations of the unsampled, intermediate waters to the Poplar River can be estimated through loading calculations by using the mean or median seasonal values of a variable at appropriate sampling sites in association with the average flows of these stations for this same period of time. Such calculations have been made for the intermediate inflows of water to the lower Poplar below the West Fork, using median concentrations, and also for the inflows of water to the Scobey-Bredette, middle reach. These calculated median concentrations for the summer season can be summarized for comparison to other chemical stream data as follows (in milligrams per liter):

	HCO_3	Cl	SO_4	Ca	Mg	TH	Na	K	D-B
Middle Reach Inputs	453	30	287	20	54	224	273	2	0.7
Lower Reach Inputs	555	214	304	24	36	217	380	15	1.0
East-Middle Fork Averages	657	11	321	33	49	275	286	15	1.8

As indicated in the above listing, the median chemistries of these intermediate input waters to the main river do not appear to be markedly different from those obtained for the major streams of the region, and this is suggestive of at least an equally good quality in these accessory types of waters as in the more discrete streams. Intermediate inflows to the lower reach of the Poplar River during the summer season apparently had slightly higher median ionic concentrations, except for magnesium, than the waters entering the upstream middle reach, and with two distinctive exceptions in the lower drainage, both of these inputs had lower concentrations of the common ions than the upstream forks of the river. As might be expected from the previous discussion, sodium and chloride represent the major deviations in this regard with respect to the lower river inflows, and the high concentrations of these two ions in the lower reach accessory waters apparently produce the significant increases in sodium and chloride that have been noted for the lower Poplar River. In association with a slight downstream decline in calcium and magnesium below Bredette, such enhancements of sodium concentrations cause the somewhat higher SAR and %Na values of the lower Poplar over the Bredette segment, and this feature may have some degradatory implications relative to the value of the lower river for irrigation uses. However, SAR and %Na levels in this Poplar mainstem reach were lower than the high values for these parameters that were obtained from the West Fork of the river.

On an overall basis, chemical changes in the Poplar Basin from its headwaters to its mouth were not particularly pronounced nor as distinct as those that have been observed in some of the other drainages in Montana such as the Yellowstone River system in the southeastern section of the State (86). For example, if chloride is excluded from the calculations, the average median difference in common ion concentrations between the East Poplar-IB samples and the Poplar-Poplar collections equalled only -3.4% for the low flow periods. Like the other Poplar drainage streams, therefore, the lower Poplar River can be characterized as having an alkaline, sodium bicarbonate-type of water with sulfate, and chloride in this one instance, representative of the secondary anionic constituents while calcium and magnesium are representative of the secondary cationic components of the stream samples. On a yearly and per weight basis, calcium and magnesium were found to be in nearly equivalent amounts in the lower river while varying to some extent by season (see Table 25); however, magnesium would be the more dominant of the two ions in the lower reach on an equivalents basis given magnesium's lower atomic weight for the same valence number. When using this latter expression, i.e., milliequivalents per liter, magnesium would be about two-times more prevalent than calcium.

In contrast to these major ions, potassium was once again an insignificant constituent of the Poplar samples, although its concentrations in this drainage were about three-times higher than the average for Montana's streams (12). Fluoride was also unimportant in the lower Poplar (Table 59), as were carbon dioxide and carbonate, although high concentrations of these latter two variables were obtained during certain seasons of the year. That is, carbonate levels were insignificant and less than those for potassium during the winter season in accompaniment with the low pH values of these months, whereas carbon dioxide was most prevalent at this particular time while being insignificant with lower concentrations than potassium during the summer, high pH season. Mean and median carbonate concentrations, meanwhile were greatest and higher than those for potassium during this same warm weather period.

Most of the same water quality features described above were also typically observed at the other Poplar drainage stations, and the more obvious changes in common constituent levels through the basin were observed to reside in the downstream increases of sodium chloride and in the downstream declines of calcium and magnesium. But regardless of these downstream chemical alterations, and in view of the concentrations of the common ions per se, it seems unlikely that any of these constituents were at adequately high or low levels in the lower Poplar to adversely influence or delimit in an individual sense the stream's aquatic biota. The major action of the individual ions in this regard would be to contribute to the river's total salinity characteristics and thereby contribute to the slight downstream fishery degradations that have been noted on this basis for the basin. However, the individual ions could have some adverse effects on certain of the "outstream" water uses such as public supply-drinking water, e.g., high total hardness (calcium and magnesium) and sulfate concentrations, and irrigation, e.g., high sodium (and %Na-SAR) values. These "outstream" aspects will be considered in more detail later in this report.

Nutrients, metals, and other constituents.

Depending upon the season, dissolved iron concentrations were either gen-

Table 59. Summary of chemical analyses of water collected from the Poplar River near Poplar (lower reach main river below the West Fork)--nutrients and other constituents.

Stat	TN	TK_jN	TON	NH_3N	NO_xN	TP	OP	COD	F	Si	D-B	D-Fe	T-Fe
November-February													
N.	5	5	5	5	5	5	5	0	5	5	5	5	0
Min	0.39	0.32	0.29	0.0	0.01	0.0	0.0	--	0.4	7.1	0.9	0.0	--
Max	0.72	0.56	0.50	0.14	0.16	0.02	0.03	--	0.5	11.	1.1	0.03	--
Mean	0.51	0.45	0.41	0.04	0.06	0.01	0.01	--	0.5	9.4	1.0	0.02	--
Med	0.51	0.50	0.42	0.01	0.03	0.02	0.0	--	0.5	9.1	1.0	0.02	--
March-May (low flows)													
N.	2	2	2	4	4	4	4	0	4	2	2	2	2
Min	0.63	0.62	0.61	<.01	<.01	0.02	0.0	--	0.4	4.4	0.5	0.02	0.28
Max	1.9	1.8	1.2	0.13	0.08	0.08	0.03	--	0.5	8.8	0.9	0.13	0.59
Mean	1.27	1.21	0.91	0.04	0.03	0.04	0.01	--	0.4	6.6	0.7	0.075	0.435
Med	1.27	1.21	0.91	<.01	0.01	0.04	0.01	--	0.4	6.6	0.7	0.075	0.435
March-May (high flows)													
N.	2	2	2	2	2	2	1	0	2	2	2	2	0
Min	0.50	0.49	0.49	0.0	0.01	0.03	--	--	0.4	5.3	0.5	0.03	--
Max	0.62	0.56	0.55	0.01	0.06	0.09	--	--	0.4	5.4	0.8	0.09	--
Mean	0.56	0.53	0.52	0.005	0.035	0.06	--	--	0.4	5.4	0.7	0.06	--
Med	0.56	0.53	0.52	0.005	0.035	0.06	0.01	--	0.4	5.4	0.7	0.06	--
March-May (extreme high flows)													
N.	1	2	1	2	2	2	2	0	2	1	1	1	2
Min	--	1.2	--	<.01	0.07	0.06	0.0	--	0.3	--	--	--	0.55
Max	--	1.3	--	0.04	0.18	0.14	0.02	--	0.3	--	--	--	2.2
Mean	--	1.25	--	0.02	0.13	0.10	0.01	--	0.3	--	--	--	1.38
Med	1.5	1.25	1.3	0.02	0.13	0.10	0.01	--	0.3	7.8	0.3	0.12	1.38
June-October (low flows)													
N.	4	7	4	8	9	8	8	0	7	6	6	6	11
Min	0.47	0.40	0.46	0.0	0.0	0.01	0.0	--	0.4	3.9	0.8	0.0	0.16
Max	1.1	1.1	0.87	0.17	0.08	0.05	0.03	--	0.5	7.4	1.6	0.10	1.45
Mean	0.79	0.63	0.65	0.04	0.03	0.03	0.01	--	0.4	5.3	1.2	0.04	0.79
Med	0.80	0.50	0.63	<.01	0.02	0.04	0.01	--	0.4	5.5	1.2	0.04	0.85
June-October (high flows)													
N.	4	5	4	5	5	5	5	0	5	4	4	4	1
Min	0.97	0.35	0.64	0.01	0.01	0.05	0.0	--	0.3	3.5	0.8	0.02	--
Max	1.4	1.4	1.4	0.11	0.03	0.13	0.02	--	0.5	8.7	1.3	0.11	--
Mean	1.14	0.98	1.02	0.03	0.02	0.08	0.01	--	0.4	6.8	1.0	0.05	--
Med	1.1	1.1	1.03	0.02	0.02	0.07	0.01	--	0.3	7.5	1.0	0.04	2.2

erally similar between the Bredette (Table 53) and Poplar (Table 59) stations on the mainstem, or they demonstrated a slight downstream increase to the lower river. However, like the middle reach, iron does not appear to be a critical parameter in the Poplar segment as has been noted for the upper drainage with all of the samples from the lower river having dissolved iron below its reference criterion (0.2 mg/l) and below its hazardous levels (0.3 mg/l) (24, 41). In turn, 60% of the Poplar station collections had dissolved iron below this metal's minimal risk levels (0.05 mg/l) in spite of iron's generally high total recoverable concentrations (Table 59).

Similar to iron, most of the remaining trace elements analyzed for the lower Poplar samples (Table 60) were also unsuggestive of water quality problems, as has been concluded previously from the Bredette data (Table 54), since only minor and negligible changes in the concentrations of these constituents became evident in a downstream direction from the middle reach to the lower Poplar station. Of the trace elements, Cd, Cr, Cu, Li, Mn, Mo, Pb, V, and Zn did appear to increase downstream to some small but noticeable degree, but such increases were inadequate to produce any violations of these element's biological reference criteria (Table 15). In addition, with the exception of total recoverable iron, no definite violations of the State's metals standards listed in Table 7 became obvious in the lower Poplar collections. As described for the Bredette samples therefore, only mercury of the nineteen trace constituents listed in Table 60 exceeded its grab sample criterion on occasion (in 26% of the cases) and was suggestive of sporadic water quality difficulties in the lower river. But inadequate data were available by which to judge the status of mercury relative to its more stringent average criterion. The implications of mercury as a critical variable in the Poplar drainage has been discussed to some detail previously.

Although the remaining trace elements are not indicative of water quality degradations at the present time, they should not be completely ignored with reference to potential impacts emanating from the Coronach development since only slight concentrational increases in many of these elements could produce water quality problems. This applies most prominently to Ag, Cd, Cu, Fe, Mn, Ni, Pb, the phenols, and Zn (and of course to Hg) since these elements were commonly observed at detectable levels in the lower river (and in the Poplar drainage) and/or since these particular constituents have relatively low reference criteria (Table 15) and have adverse biotic effects when found in comparatively minute concentrations.

In contrast to iron, boron demonstrated consistent downstream declines in concentration below Scobey through the middle and lower reaches of the Poplar River, suggestive of some dilutions from the intermediate inflows of water to the main river in Montana. The loading calculations listed previously indicate that these middle and lower reach inputs have calculated median dissolved boron levels on the order of 0.7 mg/l and 1.0 mg/l respectively for the summer season, and these concentrations are around 50%-65% lower than the median summer boron concentrations of the East Poplar River. These values of 0.7 and 1.0 mg/l in the face of an average boron concentration for Montana's streams of 0.1 mg/l (12) indicate that high boron levels are a common phenomenon of the entire Poplar drainage. However, the bulk of this constituent in the Montana reaches of the Poplar system does appear to be derived from the river's headwaters area in Canada via the East and Middle Forks. That is, about 55% of the summer boron loading in the lower river is derived from these

Table 60. Summary of chemical analyses of water collected from the Poplar River near Poplar (lower reach main river below the West Fork)--metals and miscellaneous constituents.

Stat	TOC	D-Al	T-Al	D-As	T-As	T-B	T-Ba	D-Be	T-Be
N.	9	5	12	11	15	10	2	11	6
Min	8.7	0.0	0.15	0.001	<.001	<.1	0.1	0.0	0.0
Max	27.	0.03	2.5	0.006	<.025	2.3	0.1	0.01	<.01
Mean	16.0	0.01	0.74	0.002	<.012	1.25	0.1	<.003	<.01
Med	15.	0.01	0.46	0.002	0.003	1.5	0.1	0.0	<.01

Stat	D-Cd	T-Cd	T-Co	D-Cr	T-Cr	D-Cu	T-Cu	D-Hg	T-Hg
N.	11	10	3	3	6	10	15	11	8
Min	0.0	0.0	<.01	0.0	<.01	0.0	0.004	0.0	0.0
Max	0.001	0.02	<.05	0.01	<.05	0.009	0.05	0.0008	0.0004
Mean	<.0002	<.005	<.02	0.003	<.04	0.003	<.01	0.0001	<.0002
Med	0.0	0.002	<.01	0.0	<.05	0.003	<.01	0.0	<.0002

Stat	D-Li	T-Li	D-Mn	T-Mn	D-Mo	T-Mo	D-Ni	T-Ni
N.	5	3	12	9	5	4	5	5
Min	0.07	0.08	0.0	0.04	0.0	0.004	0.001	<.01
Max	0.15	0.15	0.06	0.14	0.004	<.5	0.006	<.05
Mean	0.11	0.11	0.02	0.07	0.002	<.18	0.004	<.03
Med	0.11	0.09	0.015	0.06	0.002	<.10	0.003	0.012

Stat	D-Pb	T-Pb	D-Se	T-Se	T-Sr	D-V	T-V	D-Zn	T-Zn
N.	11	10	11	12	1	11	6	11	15
Min	0.0	0.003	0.0	0.0	--	0.0	<.10	0.0	<.005
Max	0.005	<.100	0.001	<.01	--	0.005	<.5	0.02	0.04
Mean	0.002	<.05	0.0	<.006	--	0.0017	<.16	0.007	0.01
Med	0.001	<.05	0.0	<.01	0.52	0.0014	<.11	0.002	0.01

two forks; about 8% originates in the West Fork drainage with the remaining 37% of the boron in the lower Poplar entering the river from intermediate surface and groundwater inflows in Montana. But regardless of these high levels of boron in the Poplar River, this constituent can be graded as non-critical from a hydrobiotic point of view (98).

The same conclusion derived for boron can also be applied to silica, and silica concentrations were also non-limiting to the periphyton of the lower river even though the levels of this constituent were typically below the national median value (83) and below the State's average concentration for surface waters (12). A definite decline in silica concentrations is evident in Table 59 in going from the winter to the spring and summer low flow periods, and this may have been attributable to a greater rate of silica incorporation by stream diatoms during the spans of warmer weather. However, the summer depression in silica concentrations was less pronounced in the lower river than what has been observed for some of the up-drainage reaches, and this downstream dampening of seasonal change was probably related to the greater volumes of flow in the lower portions of the Poplar, as has been outlined earlier, and/or to the reduced magnitude of primary production in the lower segments of the basin.

As described previously, the upper Poplar Basin is apparently unpolluted from obvious point source inputs, and based upon the BOD, coliform, and DO data in Table 55, this also appears to be the case for the lower Poplar River. The unpolluted aspect of the lower drainage is additionally illustrated in Table 59 by the combined nitrogen species (TN, TKjN, and TON) which had concentrations in samples from the Poplar station well below those levels that might be typically associated with even minor allochthonous organic inputs (39). In addition, the organic carbon analysis of these samples (Table 60) demonstrated TOC concentrations that were only slightly higher than the value that is commonly obtained from natural waters (87), and the maximum TOC level equalled only about 27% of the value that is common for weak domestic sewage (89). The increases in the combined nitrogen species from the winter to the summer seasons in the lower poplar (Table 59) were probably not the result of enhanced pollutive inputs during the warm weather period, but rather, related to the increased biotic activities of the summer months, and this corresponds to the decline in the inorganic nitrogen species that became evident between these same two seasons. The somewhat greater concentrational increases in combined nitrogen that occurred during the high discharge periods over the winter levels were most likely a reflection of increased nitrogen inputs via overland flow, and these inflows are best classified as either a natural feature or as a non-point source of pollution depending upon whether or not this factor was significantly aggravated by man's activities. Total phosphorus also demonstrated an increase in levels from the winter to the summer and during the high flow periods, probably for the same reasons, although inorganic phosphorous concentrations were largely insignificant in the lower Poplar reach with its OP values fairly constant at low levels through all seasons of the year.

For most practical purpbses, the concentrations of the combined nitrogen and phosphorous species tended to decline in a downstream direction from the Bredette reach on the Poplar to its lower segment, whereas the levels of the inorganic forms remained fairly constant between the Bredette and Poplar stations. A distinctive feature in Table 59 is the low inorganic nitrogen con-

centrations (NO_2-NO_3-N plus NH_3-N) of samples from the Poplar site which point to the obviously nontoxic and non-eutrophic nature of the lower river. That is, no samples were collected from the lower Poplar, even during the high flow stages, that had ammonia and TIN concentrations in excess of the reference levels for ammonia toxicity and in excess of the lower reference criterion for possible stream eutrophication. In addition, although 12% and 39% of the lower reach samples did have total phosphorous concentrations greater than this particular nutrient's upper and lower reference criteria, the mean and median TP concentrations of the Poplar segment through the low flow periods were consistently below the lower levels of phosphorus that are indicative of possible eutrophic conditions, and this would include the important warm weather, summer season. Such low TP values stand in contrast to the observations that have been made for some of the upstream reaches, e.g., the upper East Poplar River (Tables 20 and 21), which had mean and median TP levels in excess of 0.05 mg P/l for most of the seasonal periods, including the summer season but excluding the less critical winter months. Thus the lower Poplar is somewhat unique in this regard relative to the other basin streams in being both nitrogen-limited and phosphorus-limited for a major part of the year (73%), although the lower reach would be only nitrogen-limited during the high flow periods.

As a result of the above described features, the critical nutrient species, nitrogen and phosphorus, are not suggestive of water quality problems in the lower river. A quite large 31- to 45-fold increase in median TIN concentrations (or about a 13-fold increase in mean TIN levels) and a 2.5-fold increase in median TP (or a 3.3-fold increase in mean TP) would be required during the warm weather period to produce conditions in the lower Poplar River that are definitely diagnostic of stream eutrophy; in turn, minimum 12- to 18-fold and 1.3-fold summer increases in the median concentrations of these same variables would be necessary for the lower Poplar to be even suggestive of possible eutrophic conditions. Based on the previous discussions of potential downstream salinity impacts on the lower river, it appears unlikely that the Coronach development alone will be able to generate an adequate nutrient loading to the East Poplar to produce the large nutrient increases that would be needed to cause the eutrophication of the lower Poplar River. A higher probability of major impacts of this kind occurs in an upstream direction above Bredette where dilution potentials are less distinct than in the lower reach and where the pre-developmental nutrient concentrations of the stream are comparatively high at the present time and thereby more suggestive of adverse nutrient enrichments. That is, based on the current nutrient concentrations of the rivers, the upper East Poplar (Tables 20, 21, and 30) would be expected to have higher rates of primary production than the lower Poplar River, and as a result, smaller nutrient enrichments to this upstream reach would be required to produce a certain level of eutrophy than the case for the less productive, lower Poplar segment.

MINOR TRIBUTARIES

Geographic and Sampling Features

In addition to the water samples collected from the Poplar mainstem and its three major forks, some water quality collections have also been taken from several of the minor streams in the Poplar Basin. As indicated in Table 5, all of these samples, with one exception, were obtained by various Canadian

entities, and as a result, most of the associated sampling stations were located in the upper portions of the Poplar drainage in Saskatchewan. In most instances, the chemical, physical, and biological data for these small creeks are relatively incomplete in having only one sample analysis for a sampling station or in having missing values for certain of the water quality parameters that were commonly assessed at the major stream locations. However, the West Branch of the East Poplar River was sampled somewhat more extensively than the other minor streams by the Saskatchewan Department of the Environment, and the small creek feeding the Coronach town reservoir was sampled fairly intensively on a seasonal basis by Sheppard T. Powell Consultants and the Saskmont Engineering Company as they had done for the East Poplar mainstem. Thus, most of the water quality information describing these minor drainage streams is available from the East Poplar West Branch and particularly for this unnamed creek and primarily for streams located in the eastern section of the upper Poplar Basin. General conclusions concerning the quality characteristics of these particular surface waters, therefore, will be derived to a large degree from the analyses that were obtained from these two sources. The minor creeks that have been visited in the upper Poplar Basin in Canada along with the number of sample collections associated with each of the sampling stations are listed in Tables 5 and 61.

In addition to the Saskatchewan collections, single samples were also obtained from two minor surface water sources in Montana. The data from these two samples are of some added interest to the basin's quality assessments because of their collection under runoff conditions. However, most of the small streams with fairly extensive drainage areas in Montana, such as Police, Cottonwood, and Boxelder Creeks (Figure 1), had not been collected to the time of this writing. The minor Montana creeks that have been sampled are also listed in Table 5, and they are designated as streams "F" and "G" in Table 61.

Small Streams in Saskatchewan

Field parameters and common constituents.

As indicated in Table 61, dissolved oxygen concentrations were relatively high in all of the samples collected from three of the minor drainage streams, and as a result, this parameter was unsuggestive of water quality problems in these particular surface waters. However, the DO values of one of the streams (the West Branch, East Poplar River) were typically well below 100% saturation, and this feature coincides with the somewhat high BOD_5 levels that were obtained from this same creek. That is, BOD_5 concentrations were commonly above a value that can produce deoxygenations in sluggish waters (41), and this possibly accounts for the reduced DO levels of the West Branch. The high BOD's, in turn, are suggestive of some organic loading to the stream, either from natural sources, as was implicated for the upper West Fork with its high TOC concentrations, or from man's activities. The fact that coliform concentrations were relatively high in the West Branch in contrast to those of the upper West Fork and most of the other basin streams, and also on occasion in violation of Montana's standards for these constituents (44), would indicate that some pollutive inputs from municipal sources were entering the creek, and such effluents might also account for its high BOD_5 levels. But in view of the BOD's that can be developed in severely polluted streams, the municipal loadings to the West Branch would be graded as relatively mild

Table 61. Summary of chemical analyses of water collected from minor streams in the Poplar River drainage--field parameters and dissolved solids.

Stat	Flow	Temp	pH	Clr	Turb	TSS	SC	DS	DO--%Sat		BOD	TC	FC
West Branch, East Poplar River near Coronach, Canada (probably the upper reach of Girard Creek)--combined data for 1975 and 1976													
N.	0	5	6	0	0	5	6	6	4	3	6	6	6
Min	--	3.	8.0	--	--	8.	600	572	7.6	72.5	4.0	40	<10
Max	--	18.5	9.0	--	--	29.	2500	2420	10.5	95.	8.0	7000	930
Mean	--	11.9	8.55	--	--	20.8	1750	1694	9.3	83.2	5.4	1397	209
Med	--	14.5	8.65	--	--	21.	1950	1815	9.6	82.	5.0	160	40
Small Creek near Coronach, Canada													
January-February (1973 plus 1974)													
N.	0	0	3	3	3	0	3	3	0	0	0	0	0
Min	--	--	7.95	<5	2.7	--	1400	1070	--	--	--	--	--
Max	--	--	8.30	15	5.1	--	1800	1314	--	--	--	--	--
Mean	--	--	8.10	<8	3.7	--	1533	1190	--	--	--	--	--
Med	--	--	8.05	5	3.3	--	1400	1187	--	--	--	--	--
March-May (1973)													
N.	0	0	7	7	7	0	7	7	0	0	0	0	0
Min	--	--	8.25	<5	3.6	--	1250	1120	--	--	--	--	--
Max	--	--	8.53	20	14.0	--	1520	1260	--	--	--	--	--
Mean	--	--	8.37	<12	6.8	--	1399	1186	--	--	--	--	--
Med	--	--	8.36	10	5.6	--	1370	1200	--	--	--	--	--
June-October (1973 plus 1974)													
N.	0	0	24	24	24	0	24	24	0	0	0	0	0
Min	--	--	8.10	<5.	1.6	--	1228	820	--	--	--	--	--
Max	--	--	8.91	60.	13.0	--	1800	1181	--	--	--	--	--
Mean	--	--	8.43	22.	4.3	--	1459	1042	--	--	--	--	--
Med	--	--	8.40	18.5	3.05	--	1423	1035	--	--	--	--	--
Other Streams													
A	--	17.8	8.8	--	50.	62.	2378	1642	--	--	--	--	--
B	--	15.6	8.2	15	6.	40.	1211	789	--	--	--	--	--
C	--	16.7	8.3	60	20.	25.7	1495	967	--	--	--	--	--
D	--	5.	8.3	80	2.3	--	2440	1861	10.	--	--	--	--
E	--	--	8.7	50	4.3	--	2136	1429	--	--	--	--	--
F	--	6.0	7.1	70	53.	66.	255	148	9.2	--	--	--	--
G	15E	1.0	7.19	--	2500.	2320.	119	105	--	--	--	--	--

A--Fife Lake near Constance, Canada (July, 1952).
B--East Branch, Middle Poplar River near Rock Glen, Canada (June, 1964).
C--West Branch, Middle Poplar River near Rock Glen, Canada (June, 1964).
D--Middle Branch, West Poplar River near Rock Glen, Canada (October, 1974).
E--Calrick Creek near Coronach, Canada (July, 1975).
F--Cow Creek near Scobey, Montana (April, 1976)--runoff data.
G--Overland runoff north of Poplar, Montana (March, 1976).

and not degrading to the creek to any significant degree. In addition, such potential pollutive inputs to this minor tributary were largely diluted and dissipated by the time the waters reached the international border between Scobey and Coronach (see Table 17).

The color characteristics of samples from these small Canadian creeks varied to a considerable degree by season and stream (Table 61), ranging from the uncolored waters of some collections (less than ten color units) to those that were obviously colored to the human eye, e.g., greater than twenty units (32); but it would appear that the waters of these streams were most typically colored for a large portion of the time, at least during the warm weather, low flow periods. Turbidity readings were less variable and less distinct than those for color, although a few of the waters, such as Fife Lake and the Middle Poplar West Branch, did produce obviously turbid samples. But for the most part, and if data from the small Coronach creek is used as an example, turbidity does not appear to be a critical water quality variable in these minor streams. As a result, water color would tend to aesthetically degrade the creeks to some extent whereas turbidity does not appear to be a detracting factor in this regard. In addition, suspended sediment levels were most suggestive of a good to moderate fishery in these small streams (25), although this assumes that adequate flows are available by which to support a resident fishery. This latter assumption seems to be unlikely in relation to a sport fishery given the tributary nature of the creeks and the low flows of the East Poplar-IB station. However, these small streams might be used by game fish for spawning purposes.

Temperature readings taken from the small, Poplar drainage creeks were generally nondistinctive, and they were typically in accord with either a $B\text{-}D_1$ or $B\text{-}D_2$ stream classification. This corresponds to the general observation made earlier that the waters of the upper drainage appear to coincide with Montana's marginal, $B\text{-}D_2$ designation given to the entire Poplar Basin whereas the down-drainage waters become progressively more $B\text{-}D_3$ in character, particularly in the lower reach near Poplar, because of the higher downstream temperatures. Levels of pH in these small streams, with values typically ranging between 8.0 and 8.6, also corresponded to this $B\text{-}D_2$ classification as did the streams' dissolved oxygen concentrations (Table 7). However, although the lower values of pH in the Canadian creeks were consistently above 7.9 and thereby uncritical, the higher values of this variable in excess of 8.5 would largely preclude their $B\text{-}D_1$ fishery rating (44); oxygen would not be an affecting factor in this regard. Like the other Poplar Basin streams, values of pH were relatively low under the biologically inactive and reducing conditions of the winter season, but a marked increase in this variable was obtained through the spring and summer seasons probably as a result of the greater biotic activity that occurs during the warm weather periods. In a few instances, pH was elevated to adequately high levels during the summer months to degrade a good fishing water (88). These various features indicate that the waters of the minor basin streams are probably suitable for a marginal cold water fishery, although the low flows and small water volumes of these creeks and their sporadically high pH values would tend to act as limiting and restricting factors relative to the establishment of such a sport fish population.

Although fairly high levels of DS-SC were obtained in some of the samples from the small basin creeks, e.g., near 2300 umhos and 1500 mg/l (Table 61),

these values were not particularly distinctive relative to the high values on this same order that have been obtained on occasion from the major drainage streams. In addition, the high DS-SC levels in these creeks were definitely nondistinctive in relation to the values that have been listed for various small prairie systems within Montana with DS and SC levels often in the 3000 to 5000 mg/l and 4000 to 6000 umhos range (86). In turn, an average or typical level of DS and SC in these minor Poplar streams would be much lower and in the vicinity of 1360 mg/l and 1630 umhos. With reference to these comparisons, therefore, the quality of water in these small basin creeks does not appear to be all that bad. One exception could include Fife Lake which would be expected to have relatively high salinity levels on a consistent basis. The unusual spills from this lake into Girard Creek and the East Poplar drainage (Figure 1) that happened to occur during the period of sampling in the Poplar Basin probably produced the anomalously high readings of DS-SC that were measured during the periods of high summer flow in the East Poplar River, particularly at the IB station (Table 17).

On an overall basis, the DS-SC levels of the minor creeks were somewhat higher than those in the major forks, and the inflows of these types of waters into the East Poplar probably account in part for the slight downstream increases in salinity that were observed for this river from its Coronach to its Scobey sampling stations. However, the magnitudes of these tributary-mainstem differences in DS-SC varied to a considerable degree between the minor streams, being less distinct, for example, in the creek near Coronach than in the East Poplar West Branch. In addition, the creek feeding the Coronach town reservoir did not demonstrate as distinct a seasonal change in DS-SC as the major forks so that the salinity relationships between this stream and the East Poplar also varied in relation to seasons. That is, mean and median DS-SC levels of the small creek were noticeably greater than those in the East Poplar-IB during the spring season while being only about 1.11- to 1.28-times (DS) and 1.01- to 1.15-times (SC) higher than the DS-SC levels of this river during the summer and winter periods. For the most part, the salinity characteristics of the waters in these minor drainage streams should afford a good to fair fishery (Table 16), assuming that the other potential affecting factors such as flow are non-limiting.

With reference to the common constituents (Table 62), the minor streams of the basin, except for the runoff samples, can be characterized as being extremely hard, slightly saline (58), and highly alkaline in nature while having, like the rest of the drainage streams, a distinctive sodium bicarbonate-type of water. Because of the high sodium concentrations, SAR and %Na values in most of the samples from the small creeks were relatively high and typically in excess of 70% in the latter case. Like sodium, sulfate was also a prevalent constituent of the collections and representative of the secondary anion whereas calcium and magnesium were less abundant than sulfate but representative of the streams' secondary cations. Ca/Mg ratios varied by creek and season and ranged from values that were significantly less than one to values that were considerably greater than one, although a few of the samples did have Ca/Mg ratios that were fairly close to unity. In contrast to these major ions, chloride and potassium were again insignificant components of the creek collections; however, some of the samples did demonstrate somewhat high potassium levels that were greater than the concentrations typically obtained from the major drainage forks and the mainstem. Carbonate-phenolphthalein (PA) levels in the creeks were also insignificant in the low pH samples; but with the higher pH's, the concentrations of these variables became

Table 62. Summary of chemical analyses of water collected from minor streams in the Poplar River drainage--common constituents.

Stat	CO_2	HCO_3	CO_3	TA	PA	Cl	SO_4	Ca	Mg	TH	Na	SAR	%Na	K
West Branch, East Poplar River near Coronach, Canada (probably the upper reach of Girard Creek)--combined data for 1975 and 1976														
N.	0	6	6	6	4	6	6	6	6	6	6	0	0	6
Min	--	232	0.0	190	30	11.	176	22.	27.	212	79	--	--	12.
Max	--	1179	125.	966	140	30.	600	104.	101.	640	439	--	--	40.
Mean	--	687	56.	656	79	18.0	446	44.3	69.0	396	345	--	--	27.8
Med	--	678	54.	683	72	17.	510	33.5	69.	382	408	--	--	29.
Small Creek near Coronach, Canada														
January-February (1973 plus 1974)														
N.	0	0	0	3	3	3	3	3	3	3	3	0	0	3
Min	--	--	--	532	0.0	6.8	344	63.	57.	392	232	--	--	11.
Max	--	--	--	728	0.0	9.6	405	90.	68.	505	293	--	--	13.
Mean	--	--	--	631	0.0	8.0	375	80.3	62.3	456	265	--	--	12.0
Med	--	--	--	632	0.0	7.5	375	88.	62.	470	270	--	--	12.
March-May (1973)														
N.	0	0	0	7	7	7	7	7	7	7	7	0	0	7
Min	--	--	--	496	0.0	0.3	200	50.	60.	372	120	--	--	7.5
Max	--	--	--	581	10.	1.0	385	100.	66.	518	213	--	--	18.8
Mean	--	--	--	543	2.7	0.5	277	71.7	62.4	438	172	--	--	13.9
Med	--	--	--	548	0.0	0.5	245	72.	63.	442	170	--	--	15.0
June-October (1973 plus 1974)														
N.	0	0	0	24	24	24	24	24	24	24	24	0	0	24
Min	--	--	--	357	0.0	<.1	146	17.	25.	173	160	--	--	8.8
Max	--	--	--	529	56.	8.9	472	55.	66.	389	315	--	--	14.
Mean	--	--	--	499	16.	3.9	358	40.6	53.0	320	248	--	--	11.3
Med	--	--	--	506	16.	4.6	362	43.	53.5	325	244	--	--	11.
Other Streams														
A	--	660	108.	--	--	17.5	608	11.2	78.8	352	450	--	70.7	40.5
B	6.	596	0.0	489	0.0	3.9	211	58.2	58.2	385	150	3.3	45.	7.3
C	6.	737	0.0	605	0.0	6.1	225	17.8	32.4	178	302	9.9	77.	12.0
D	8.0	1004	0.0	824	0.0	13.	665	84.	37.	362	550	--	75.9	15.
E	2.7	701	74.	699	62.	14.0	528	21.8	60.1	302	426	--	73.0	32.7
F	5.6	114	0.0	94	0.0	2.	29	21.	<.1	53	18	--	36.4	12.4
G	--	57	0.0	47	0.0	1.5	15	16.8	4.4	60	1.0	0.1	--	8.1

A--Fife Lake near Constance, Canada (July, 1952).
B--East Branch, Middle Poplar River near Rock Glen, Canada (June, 1964).
C--West Branch, Middle Poplar River near Rock Glen, Canada (June, 1964).
D--Middle Branch, West Poplar River near Rock Glen, Canada (October, 1974).
E--Calrick Creek near Coronach, Canada (July, 1975).
F--Cow Creek near Scobey, Montana (April, 1976)--runoff data.
G--Overland runoff north of Poplar, Montana (March, 1976).

more pronounced, and the opposite pH relationship was shown for carbon dioxide.

In association with the high DS-SC levels of the minor creeks, the concentrations of some of the major ionic constituents were quite distinct in the collections, and this was particularly true for bicarbonate, sulfate, and sodium. These three ions accounted for an average of 46%, 25%, and 20%, respectively, of the creeks' salinity levels while affording between 87% and 96% of the total dissolved solids content in the several samples collected from the small basin streams. But outside of contributing to the waters' salinity and osmotic characteristics, none of the various ions, whether in high or low concentrations, would be expected to affect the aquatic biota on an individual basis to any significant degree. The major concern in this regard should be directed to the various "outstream" water uses.

Nutrients, metals, and other constituents.

Similar to the case for chloride, fluoride (Table 63) was also an insignificant component of those minor creeks that were assessed for this particular ion. Silica levels were also nondistinct, and they were generally similar to the concentrations that were obtained from the major basin streams. Like the lower Poplar, silica in the small creeks was typically below the State's average for surface waters and below the national median for this constituent (12, 83); but in contrast to the mainstem, silica was also at adequately low levels in a few instances, e.g., in Fife Lake, to begin to approach the limiting levels for diatom development (80). As observed for the various mainstem forks, a slight winter to summer decline in silica also became evident in the small creek near Coronach. However, this silica depression was much less pronounced, for example, than those described for the East Poplar River (Tables 20, 26, and 30). Therefore, with the exception of a few creek samples and the Fife Lake collection, silica was not indicative of a critical water quality parameter in the minor drainage waters.

As indicated in Table 63, iron concentrations, both total recoverable and dissolved, were quite variable among the small basin streams. In a few instances, dissolved iron exceeded this metal's reference criteria for the aquatic biota (41) which points to the occurrence of occasional water quality problems. However, these types of data were not particularly abundant for the creeks. Using the TR/D ratio for iron and the associated rationale described previously for application to this metal's TR data, i.e., a ratio of 2.5 with a 96% confidence level, iron was found to exceed its biological reference level in about 22% of the samples while being in excess of its hazardous levels in about 4% of the cases. These analyses also indicate that iron might have some sporadic effects on the aquatic biota of the creeks, and this appears to be the general case for the entire upper portion of the Poplar Basin. Iron concentrations in these small streams also exceeded the State's criteria for this element on several occasions (44). But outside of iron, the dissolved metals data in Table 64 and a TR/D application to these other elements were not, in most instances, indicative of water quality problems in the minor streams, at least in relation to the reference criteria in Tables 7 and 15. The trace elements that can be most obviously added to such a non-problem listing would include Cu, Mn, Pb, and Zn because of their large numbers of analyses, but it also could include Al and Cd.

Table 63. Summary of chemical analyses of water collected from minor streams in the Poplar River drainage--nutrients and other constituents.

Stat	TN	TK_JN	TON	NH_3N	NO_XN	TP	OP	COD	F	Si	D-B	D-Fe	T-Fe
West Branch, East Poplar River near Coronach, Canada (probably the upper reach of Girard Creek)--combined data for 1975 and 1976													
N.	0	6	0	6	6	6	6	0	0	0	0	0	6
Min	--	1.5	--	0.08	<.02	0.06	0.01	--	--	--	--	--	0.2
Max	--	4.7	--	1.3	0.69	0.51	0.46	--	--	--	--	--	0.9
Mean	--	2.87	--	0.51	<.18	0.15	0.10	--	--	--	--	--	0.52
Med	--	3.0	--	0.40	<.1	0.09	0.02	--	--	--	--	--	0.5
Small Creek near Coronach, Canada													
January-February (1973 plus 1974)													
N.	0	0	0	3	3	3	3	3	0	3	0	0	3
Min	--	--	--	0.40	0.05	0.01	<.01	13.	--	1.8	--	--	0.18
Max	--	--	--	0.63	0.09	0.02	0.02	18.	--	13.3	--	--	0.50
Mean	--	--	--	0.51	0.07	0.017	0.01	16.3	--	7.5	--	--	0.35
Med	--	--	--	0.5	0.07	0.02	0.01	18.	--	7.3	--	--	0.38
March-May (1973)													
N.	0	0	0	7	7	7	7	7	0	7	0	0	7
Min	--	--	--	<.05	0.07	0.04	<.01	23.2	--	5.6	--	--	0.15
Max	--	--	--	0.08	0.12	0.07	0.06	30.8	--	7.8	--	--	0.35
Mean	--	--	--	<.05	0.10	0.06	<.02	26.5	--	7.0	--	--	0.24
Med	--	--	--	<.05	0.10	0.06	<.01	25.9	--	7.1	--	--	0.22
June-October (1973 plus 1974)													
N.	0	0	0	24	24	24	24	24	0	24	0	0	24
Min	--	--	--	0.1	0.04	<.01	<.01	12.9	--	1.8	--	--	0.12
Max	--	--	--	1.1	0.23	0.18	0.02	40.2	--	9.6	--	--	0.63
Mean	--	--	--	0.43	0.10	0.06	<.01	23.0	--	5.0	--	--	0.31
Med	--	--	--	0.40	0.10	0.04	<.01	22.0	--	5.1	--	--	0.24
Other Streams													
A	--	--	--	--	0.36	--	--	--	--	1.1	--	0.14	--
B	--	--	--	--	0.03	0.0	--	--	0.4	6.6	--	0.0	--
C	--	--	--	--	0.25	0.1	--	--	0.7	5.0	--	0.0	--
D	--	1.2	--	--	0.01	0.04	--	--	0.0	2.6	--	0.31	--
E	--	1.6	--	--	0.01	1.3	--	--	0.2	0.6	--	--	--
F	--	1.5	--	<.01	0.12	0.21	--	--	0.1	9.	0.3	1.0	1.6
G	--	9.0	--	0.03	0.51	1.9	0.25	--	0.1	--	--	--	--

A--Fife Lake near Constance, Canada (July, 1952).
B--East Branch, Middle Poplar River near Rock Glen, Canada (June, 1964).
C--West Branch, Middle Poplar River near Rock Glen, Canada (June, 1964).
D--Middle Branch, West Poplar River near Rock Glen, Canada (October, 1974).
E--Calrick Creek near Coronach, Canada (July, 1975).
F--Cow Creek near Scobey, Montana (April, 1976)--runoff data.
G--Overland runoff north of Poplar, Montana (March, 1976).

Table 64. Summary of chemical analyses of water collected from minor streams in the Poplar River drainage--metals and miscellaneous constituents.

West Branch, East Poplar River near Coronach, Canada (probably the upper reach of Girard Creek)--combined data for 1975 and 1976.

Stat	T-B	T-Mn	TOC	Chl (ug/l)
N.	2	6	5	2
Min	2.02	<.01	6.	2.3
Max	3.8	0.04	34.	16.
Mean	2.91	<.018	17.4	9.15
Med	2.91	<.01	17.	9.15

Small Creek near Coronach, Canada

Stat	T-Cu	T-Hg	T-Mn	T-Pb	T-Zn
N.	34	6	34	10	34
Min	<.01	<.00005	<.01	<.01	<.01
Max	0.18	0.00015	0.11	0.03	0.08
Mean	<.016	<.00007	0.045	<.019	<.019
Med	<.01	<.00005	0.04	<.02	0.01

Other Streams

Stat	T-Al	T-B	T-Cd	T-Cu	T-Mn	D-Mn	T-Pb	T-Zn	TOC	Chl (ug/l)
A	--	4.0, 4.1	--	--	--	--	--	--	--	--
B	0.11	--	--	--	--	0.0	--	--	--	--
C	0.06	--	--	--	--	0.0	--	--	--	--
D	--	--	0.002	<.001	0.02	--	0.004	0.001	21	12
E	--	--	0.001	0.004	0.024	<.01	0.005	<.001	16	<5
G	--	<.1	--	--	--	--	--	--	--	--

Stat	D-As	T-As	T-Ba	T-Be	D-Cd	T-Hg	D-Pb	D-Se	T-V	Phenols	Pesticides (ug/l)
A	--	0.05	--	--	--	--	--	--	--	--	--
D	--	--	<.05	--	--	--	--	--	--	--	--
E	0.004			<.005	0.001	0.00006	<.004	<.0005	<.001	0.011	<.011

A--Fife Lake near Constance, Canada (July, 1952)
B--East Branch, Middle Poplar River near Rock Glen, Canada (June, 1964).
C--West Branch, Middle Poplar River near Rock Glen, Canada (June, 1964).
D--Middle Branch, West Poplar River near Rock Glen, Canada (October, 1974).
E--Calrick Creek near Coronach, Canada (July, 1975).
G--Overland runoff north of Poplar, Montana (March, 1976).

As is characteristic of the Poplar drainage, mercury apparently affords the major exception to the non-problem nature of trace elements in the small creeks by demonstrating concentrations that were potentially greater than its biotic reference criteria on a few occasions. In addition, boron was found in distinctively high concentrations in these minor streams, and also in Fife Lake (Table 63), and this feature corresponds to the general observation made earlier that a large percentage of the boron levels in the major drainage waters is probably derived from the headwaters area, i.e., via the inflows from these small tributaries plus the associated groundwaters. But in this case and regardless of the high boron values, no effects on the creeks' aquatic biota would be anticipated based on Wurtz's (1945) assessments, although "outstream" water uses might be adversely influenced by this constituent.

Concentrations of the nitrogen and phosphorous species were also quite variable among the minor streams of the Poplar Basin (Table 63). But for the most part, the few data that are available for the combined nitrogen variables, and the ammonia and nitrite-nitrate data, do point to the occurrence of relatively high concentrations of these constituents in the creeks. These high levels, in turn, correspond to and probably account for the high nitrogen concentrations in the major basin forks. However, these variables were not at adequate levels to be suggestive of pollutive inputs to the streams, and this conclusion is generally confirmed by the creeks' COD (Table 63) and TOC (Table 64) analyses. These latter two parameters indicate that the organic contents of the minor creeks were slightly greater than what might be expected from most natural, unpolluted waters (87), which coincides with the BOD information, but the COD and TOC values of the Poplar streams were not sufficiently high to be indicative of severe organic pollution. Although some organic inputs via pollutive sources have been suggested for the East Poplar West Branch because of its high fecal levels, it would seem much more likely that the organics in these small streams were derived primarily from natural features such as swampy and marshy areas in the headwaters region. As observed for the rest of the basin, organic-municipal pollution does not appear to be a distinctive water quality problem for these particular streams.

In opposition to these small organic loadings, ammonia was more descriptive of a problem parameter in these creeks in being at adequate levels in some samples (Table 63) to afford possible biotic toxicities in its non-ionic form, particularly in conjunction with the higher pH values near 9.0 as has been described for the East Poplar River. From a different viewpoint, ammonia also has to be considered as a critical nutrient. In contrast to ammonia and nitrite-nitrate, inorganic phosphorous (orthophosphate) concentrations were largely insignificant in the streams, although total phosphorus was at adequately high levels to be suggestive of eutrophic conditions. Such high TP values plus the high NH_3-N, $NO_2 + NO_3$ - N, and TIN concentrations of most samples from the minor drainage creeks point to the possibility of stream eutrophy. But like the East Poplar (Table 21), this status cannot be definitely confirmed on the basis of chemical data alone since the TIN and TP concentrations of the samples were typically below these nutrient's more diagnostic upper criteria (i.e., 0.90 mg N/l and 0.10 mg P/l) while being most commonly in excess of the lower reference levels (i.e., 0.35 mg N/l and 0.05 mg P/l). In addition, the chlorophyll concentrations that have been obtained from the minor creeks and the upper East Poplar (Tables 22 and 64) were most akin to those that are commonly found in mildly productive but non-eutrophic systems in Montana (81, 97), with the chlorophyll data of these various wa-

ters thereby unsuggestive of eutrophic conditions. As a result of this dichotomy, in situ production measurements will have to be eventually made in order to document the eutrophic nature of the basin creeks and the upper East Poplar River.

Small Streams in Montana

Field parameters and common constituents.

The most distinctive features of the two small stream runoff samples collected from the Montana portion of the Poplar Basin reside in their markedly low DS-SC levels and in their comparatively high suspended sediment-turbidity values (Table 61, streams "F" and "G"), and the latter feature was particularly pronounced in the water obtained directly from an overland flow source. These runoff samples were collected during the spring months of high flow in the Poplar mainstem and its forks, and the inputs of such accessory waters to the main stream courses no doubt account for the declines in DS-SC levels that were observed for these rivers during the March-May period (e.g., see Tables 23, 46, and 55). Such inputs can also account for the marked increases in flow and the increases in suspended sediment-turbidity that were found to occur during this same season.

Two types of suspended sediment-turbidity enhancements became evident in the Poplar mainstem and its forks from the winter low flow to the spring and summer high flow periods: (1) relatively slight or often nondistinctive inter-seasonal increases in these variables in direct correspondence with the increases in flow as illustrated in Tables 17 and 46; and (2) a much more marked increase in suspended sediment-turbidity from the winter to the spring, as illustrated in Table 51, that was only infrequently observed for the various drainage streams. The moderate and more common increases in suspended sediment-turbidity were probably due to the Cow Creek-type of inputs (Table 61) when the spring flows of the basin streams were not at their peak levels; the more marked increases in these variables were probably due to the overland flow-type of inputs from active snowmelt in the region when the main rivers were very near their discharge maximums for a water year. The relative infrequency of detecting the extremely high suspended sediment-turbidity levels in the main stream courses was most likely related to the rapid and time-variable onset of these discharge peaks, e.g., a 1000- to 2000-fold increase in flow developing within a five to ten day period from early March to late April, and to the short duration of these peaks, lasting on the order of only ten days, in the face of regular and fixed sampling schedules that could easily miss these short-term runoff events. As a result, additional sampling will be required in the Poplar drainage before the suspended sediment characteristics of its streams can be adequately defined in relation to their high runoff periods.

In contrast to DS-SC, the dissolved oxygen and temperature levels of the small stream runoff samples were largely nondistinctive in relation to the other basin samples. However, the low pH levels of these runoff waters did standout in comparison to the other Poplar streams, and this feature corresponds to the low pH's that were observed for the major streams during the spring versus the summer season. However, such low values of pH were inadequate to be an affecting factor from a biological point of view.

In association with the extremely dilute dissolved solids levels, the concentrations of the various common constituents in the Montana runoff samples were also markedly low (Table 62). In these cases, chloride, fluoride (Table 63), potassium, magnesium, and even sodium and sulfate were representative of insignificant components in these particular samples with the waters primarily calcium bicarbonate in character. Because of the low sodium concentrations, the SAR and %Na values of the runoff collections were also quite small. However, although potassium like sodium was an unimportant constituent, it did have somewhat higher concentrations than what might be expected in relation to the marked dilutions that were obtained for the other ionic components such as sodium and sulfate; that is, sodium and sulfate in the Cow Creek collection (stream "F") were at 4% and 5% of that in the non-runoff, Calrick Creek sample (stream "E") while potassium stood at 38% for the same comparison. Similar runoff and non-runoff relationships with respect to potassium were also found to hold for the major drainage streams. In addition, the calcium bicarbonate nature of these runoff waters also corresponded to, with their inflows to the larger basin streams probably accounting for, the tendency of these rivers to become more calcium bicarbonate in flavor with lower SAR-%Na values during the spring period (see Table 25). Such inputs would also explain the noticeable lack of change in the winter to spring to summer potassium levels of the major drainage waters, e.g., Tables 19, 41, 48, and 58.

Nutrients, metals, and other constituents.

Silica levels in the small stream runoff samples from Montana (Table 63) were about equal to the State's average for this constituent (12). But like the case for potassium, such concentrations of silica might be viewed as markedly high in view of the distinct runoff dilutions that were obtained for the other common constituents, as has been noted previously. This feature suggests that these runoff waters picked-up considerable quantities of silica and potassium (along with iron, sediment, and the various nutrient species) from overland flow. As a result, iron concentrations in these runoff collections were also relatively high and indicative of some adverse effects on the aquatic biota. As might be expected, these high iron levels paralleled the increases in this variable that were observed for the major basin streams during the higher flows of the spring season. But apart from iron, none of the remaining trace elements (Table 64), including three pesticides (lindane, 2,4-D, and 2,4,5-T) and boron, pointed to the occurrence of biological water quality problems.

In contrast to the pesticides, phenol was detected in the runoff samples (Table 64), but the concentration of this variable was below the levels required to drastically effect aquatic orgasms and to taint fish flesh (Table 15). However, since the level of phenol was above the reference criteria utilized by the Environmental Protection Agency in their National Water Quality Inventory (68), it might be graded as a critical water quality variable in these particular runoff collections. But as described previously, this parameter can be derived from natural sources (33), and this appears to be the most likely case for these accessory waters rather than some pollutive source, especially in view of the fact that somewhat high organic levels were commonly found in the small drainage streams.

Both the combined and the inorganic forms of the nutrient species, ex-

cluding ammonia-nitrogen, were found in distinctively high concentrations in the small stream runoff collections (Table 63), and they were at adequate levels to be suggestive of eutrophic conditions. However, with the low pH values of the samples and with their low ammonia levels, these waters would not present toxic conditions to the aquatic biota (24). The high Kjeldahl nitrogen and total phosphorous concentrations of these runoff collections, which were particularly distinct in sample "C", indicate that these accessory waters picked-up considerable quantities of the combined nutrient species off the land via the overland flow component of the streams' discharge. In addition, considerable quantities of the inorganic forms of these nutrients, i.e., orthophosphate and nitrite-nitrate, were also garnered in this fashion. The inputs of these runoff waters to the main stream courses of the Poplar River Basin apparently caused the increases in the combined and inorganic, nitrogen and phosphorous species that were observed in the major drainage streams during the spring season. Since the Poplar drainage is primarily an agricultural area (Table 3), it might be assumed that at least a portion of the nitrogen and phosphorus (and potassium) that was washed-off the land and into the streams via overland flow was probably derived originally from farming activities in the region, e.g., from fertilizer applications. As a result, these nutrient-laden, March-May inputs to the various Poplar streams might be viewed as non-point sources of pollution.

The same reasoning directed to the nutrients can also be applied to the high suspended sediment concentrations that were obtained from the small stream runoff collections since these high concentrations were also ultimately reflected by the high suspended sediment and turbidity levels of the major drainage rivers. In this case, the high sediment levels of the runoff waters probably stemmed from the surface erosion of cultivated and overgrazed agricultural lands lying near the basin's streams. Therefore, and as indicated previously, such non-point pollution features and the water quality parameters that are associated with this type of input, e.g., nutrients and sediment, appear to be much more critical to the basin's waters than the kinds of pollution that are derived from obvious point sources such as municipal effluents. The water quality parameters that are commonly associated with point source discharges, e.g., coliforms and BOD, do not appear to pose a significant degradatory problem to the Poplar drainage whereas the non-point parameters, excluding the pesticides, are much more distinctive in this regard.

SITE INVENTORY--WATER-USE SPECIFIC QUALITY ASSESSMENTS

AGRICULTURAL USES

Stock Water

General Features and Field Parameters.

The Poplar River Task Force (1976b) in their evaluations of water use in the Poplar Basin included the water required for household, livestock, and garden irrigation needs under a single "domestic use" category. Household and garden irrigation uses were assumed to be negligible so that the primary domestic application was that utilized for the watering of stock animals. But as indicated in Table 4, stock watering was also a relatively minor use of water in the study region, representing only about 9% of the total basin consumption and only about 1% of the natural discharge in the drainage during an average water year. Nevertheless, a large proportion of the land in the Poplar Basin is devoted to livestock enterprises (Table 3), and this endeavor accounted for 28% of the total agricultural cash receipts for the region in 1967 (75). As a result, water quality evaluations should also be directed to the use of the Poplar streams for stock purposes.

The reference criteria for those water quality parameters that can have a direct effect on the use of a stream for stock water are summarized in Table 8. As indicated by this table, most of the "field" parameters, except for pH and dissolved solids-specific conductance, are not applicable as a basis of judgement in this regard since criteria for these variables have not been established for various reasons. In most instances, these parameters can be simply viewed as non-affecting factors. Temperature serves as an obvious example, although common sense dictates that certain high extremes of this variable not typically found in natural systems would be unsuitable for this use. Flow also affords some common sense extremes. In turn, stock water criteria have not been developed for BOD, suspended sediment-turbidity, and color (16, 24, 41, 48, 114).

In the case of dissolved oxygen-%Sat, McKee and Wolf (1963) indicate that on " . . . the basis of the available information . . ., it is not feasible to attempt to suggest an optimum dissolved-oxygen content of water for . . . stock and wildlife . . . uses." However, with reference to livestock, the Environmental Studies Board (1973) points out that water " . . . has a vital role in environments favorable for anaerobic infections caused by Clostridia." They further suggest that the management " . . . of water to avoid oxygen depletion serves to control the anaerobic problem. Temporary or permanent areas of anaerobic water environment are dangerous to livestock. Domestic animals should be prevented from consuming water not adequately oxygenated." On this basis, therefore, waters with DO levels increasingly near 100% saturation would appear to be progressively more ideal for stock watering purposes. Waters in the Poplar Basin on most occasions closely coincided with this 100% DO value, although the sporadic winter depressions in DO that were observed from some of the drainage streams might be suggestive of temporary problems of this nature. Fortunately, the spans of low DO concentrations in the streams were relatively short-lived, and some quantities of DO were found in the waters even during this depression period which would tend to negate this potential problem to a considerable extent.

No reference criteria have been established for the bacterial pathogens of livestock in relation to their acceptable water concentrations (41) even though one " . . . of the most significant factors in the spread of infectious diseases of domesticated animals is the quality of water which they consume (24)." But direct " . . . evidence relating the occurrence of animal pathogens in surface waters and disease outbreaks is limited (24)." Possible animal diseases that might be spread by water have been listed by the Environmental Studies Board (1973), and these would include listeriosis, leptospirosis, and bacillary hemoglobinuria, among others. However, this type of data is not now available for the Poplar Basin by which to judge the likelihood of such disease transference via the drainage streams.

With respect to the coliform bacteria that were assessed in the basin sampling programs, these organisms can cause urinary diseases, abscesses, and mastitis in livestock (24). The coliforms are so widely spread in nature that some contaminations of this kind are to be expected, but the invasiveness of these organisms is so low that such infections are typically regarded as accidents (48). For example, Snyder (1951), and others, have reported cows to be free of disease even when consuming water directly contaminated by sewage and pathogenic bacteria. As a result, reference criteria for the coliform group of bacteria in waters are also unavailable in relation to livestock use. In the main, coliform bacteria are not typically viewed as disease-causing organisms, but since they are commonly associated with the guts and feces of animals, including man, these bacteria are utilized as indicator organisms for establishing the likelihood of pathogens in a water. That is, high concentrations of fecal coliforms in a water sample may point to the presence of disease-causing organisms in the water's source. This test is commonly applied to waters utilized for human consumption, and if the same type of reasoning can also be applied to stock animals, then the Poplar River Basin is generally unsuggestive of disease-related problems because of the low coliform counts that were typically obtained from its various streams (e.g., Tables 17 and 44).

Of the "field" parameters, only pH and salinity (DS-SC) have an obvious and direct effect on the value of a water for stock applications, and the salinity aspect will be considered in the following section of this report. In the case of the first variable, the several "field" parameter, tabular summaries for the various Poplar stations, which include pH, indicate that the minimum threshold and limiting reference values for pH listed in Table 8 were never achieved in the drainage waters with this variable thereby non-limiting from the "lower end." The high pH values of the Poplar waters were much more critical in this regard. Depending upon season, the upper threshold level of pH was commonly exceeded by the stream samples, indicative of some relatively mild physiological effects, whereas the upper limiting value of pH, which is suggestive of marked impairments to the animals after extended consumption, was also exceeded by the basin collections on some occasions. The East Poplar near Coronach was least distinctive in this regard (Table 28), pointing to an absence of water quality degradations, while the pH values of samples from Girard Creek were quite pronounced in this manner (Tables 32 and 61) and indicative of a poor quality of water for livestock use.

With respect to the other drainage streams (Tables 17, 23, 35, 39, 44, 46, 51, 55, and 61), the following seasonal summaries generally describe

their pH characteristics: winter--threshold levels rarely and limiting values of pH never exceeded by these samples, i.e., mean and median pH's well below 8.5 and maximum pH's well below 9.0 and consistently below 8.5; spring--threshold levels occasionally and limiting values of pH never exceeded by these collections, i.e., mean and median pH's below 8.5 with maximum pH's below 9.0 but occasionally above 8.5; summer--threshold levels commonly and limiting values of pH occasionally exceeded by these samples, i.e., mean and median pH's commonly above 8.5 with maximum pH's occasionally above 9.0 and consistently well above 8.5. These summaries suggest that pH does degrade the value of these Poplar waters for stock applications to some extent, but this occurs primarily during the summer season with the winter and spring samples suggestive of a good to excellent quality for livestock consumption. The fact that the limiting values of pH were only infrequently attained during the summer period (e.g., in 11% of the collections) would preclude an extended consumption of the high pH waters, and as a result, these warm weather sources, except for Girard Creek, are also probably suitable for stock animals with only mild threshold effects. However, any overall increases of pH in the streams above these background levels, as might result from the Coronach development, would cause additional quality reductions relative to this water use, and this would be particularly distinctive during the summer season.

Dissolved solids and common constituents.

In contrast to most of the "field" parameters, many of the common constituents do have individual livestock reference criteria as listed in Table 8 in addition to contributing to the total dissolved solids levels of a water which is an extremely important variable to consider in any evaluations of this particular water use. However, some of the parameters listed in the various common constituent tabular summaries presented previously in this report (e.g., Table 58) might be also viewed as non-affecting factors. Most obvious in this regard are SAR and %Na which are derived parameters that have their primary application to irrigation considerations. Total hardness is a variable of this same ilk which is applicable primarily to the domestic- and industrial-use aspects of a water. Phenolphthalein alkalinity (PA) is a subset expression of the total buffering capacity of a water (TA) and is generally related to carbonate concentrations. In turn, although a water's buffering capacity is an important water quality feature, no livestock reference criteria have been established for carbonate and PA or for carbon dioxide (16, 24, 41, 48, 114). This also applies to potassium, although some potassium salts such as $KHCO_3$, KCl, and KNO_3 (saltpeter) do have toxic effects on stock animals when in relatively high concentrations, i.e., in excess of 2000 mg/l for $KHCO_3$ and KCl (sheep and chicks) and in excess of 20g for saltpeter (horses, cows, sheep, swine, and man) (41). But in the case of this variable, the concentrations of potassium and the associated anionic radicals were much too low in the Poplar Basin streams to be suggestive of these types of water quality problems. The concentrations of carbon dioxide and carbonate were also quite low and unsuggestive of quality degradations.

Reference criteria relative to the use of a water for stock consumption have been established for bicarbonate, chloride, sulfate, calcium, magnesium, and sodium (16). Although the concentrations of some of these ions were relatively high in the Poplar streams, e.g., bicarbonate, sulfate, and sodium, most of these ions had their mean and median levels well below the corres-

ponding threshold and limiting values (Table 8). As indicated in Table 65, chloride and calcium were most distinct in this respect with consistently high L/I ratios (as defined in the table) and with the maximum concentrations of these two variables in the drainage collections also well below their threshold (and limiting) levels. In the case of magnesium and sodium, the L/I ratios were somewhat lower, but sample concentrations were again always less than the threshold level with their maximum concentrations standing at 50% to 60% of this reference value. Of the common ions, therefore, bicarbonate and sulfate had the lowest L/I values and were most suggestive of water quality problems. However, the mean and median concentrations of sulfate were found to be in excess of its threshold value on a few occasions, but they were never in excess of the limiting level for stock animal watering. These aspects of sulfate are indicative of some sporadic but relatively mild water quality degradations in the Poplar streams, and for the most part, this anion, along with chloride, calcium, magnesium, and sodium, point to a relatively good quality for livestock applications.

In most instances, the various L/I values (Table 65) indicate that fairly large concentrational increases in some of these ions might be tolerated in the Poplar streams without degrading the value of the water for stock consumption. This of course assumes that any combination of such ionic increases would not cause the dissolved solids levels of the stream to exceed its particular reference criteria. The largest ionic increase that might be tolerated is in the form of chloride because of its extremely high L/I values, although calcium, magnesium, and sodium should also allow for fairly large increases in the Poplar streams without degrading these waters for stock applications to any significant degree. Bicarbonate and sulfate, in turn, would be the most limiting of the ions from this standpoint in view of their low L/I factors.

Based on the reference criteria established by the California State Water Quality Control Board (1963), the high bicarbonate concentrations that characterize the Poplar streams should definitely detract from the quality of the basin's waters for livestock uses. Mean and median concentrations of this constituent were consistently above its reference values at the various Poplar drainage stations, and its L/I values were generally less than one except for the spring season at several locations; in addition, the higher concentrations of bicarbonate were at times in excess of two-times greater than its reference levels. However, bicarbonate reference criteria for stock animals have not been listed by several other authorities (24, 41, 48, 114) which would indicate that this constituent is a noncritical factor in this regard. But McKee and Wolf (1963) do point out that high alkalinities have been reported to be detrimental to domesticated stock, and such animals have been observed to develop diarrhea at a total alkalinity of 170 mg/l; the alkalinities of the Poplar streams were much higher than this value. In any event, the available data does suggest that further increases of bicarbonate and total alkalinity (which also includes the carbonate component) would certainly be an unfavorable occurrence in the Poplar streams in relation to the use of these waters for refreshing stock animals.

The mean and median dissolved solids concentrations of the various Poplar streams also point to a good quality of water for livestock use as defined by the grading systems developed by the States of Montana and South Dakota (5, 61). The L/DS ratios of Table 65 were consistently greater than

Table 65. Ratios (R) by season of the median concentration of various common ions (I)-dissolved solids (DS) in the Poplar Basin streams and these constituents' threshold and limiting levels (L) for stock animals as established by the California State Water Quality Control Board (1963), where R = L/I or DS (IB--international boundary).

	Winter Low Flow							Spring Low Flow							Summer Low Flow						
	DS	HCO_3	Cl	SO_4	Ca	Mg	Na	DS	HCO_3	Cl	SO_4	Ca	Mg	Na	DS	HCO_3	Cl	SO_4	Ca	Mg	Na
Unnamed Creek-Coronach																					
Threshold	2.1	--	>99	1.3	5.7	4.0	3.7	2.1	--	>99	2.0	6.9	4.0	5.9	2.4	--	>99	1.4	12.	4.7	4.1
Limiting	4.2	--	>99	2.7	11.	8.1	7.4	4.2	--	>99	4.1	14.	7.9	12.	4.8	--	>99	2.8	23.	9.3	8.2
Girard Creek--Coronach																					
Threshold	4.6	--	>99	2.8	21.	8.6	8.1	4.1	--	>99	4.6	10.	6.6	16.	3.9	--	>99	2.3	29.	6.9	6.2
Limiting	9.2	--	>99	5.5	42.	17.	16.	8.1	--	>99	9.3	21.	13.	32.	7.8	--	>99	4.7	57.	14.	12.
East Poplar-Coronach																					
Threshold	2.9	0.79	>99	2.7	6.7	4.8	6.4	3.4	0.94	>99	3.6	8.5	5.4	11.	3.1	0.82	>99	2.6	7.4	5.0	7.2
Limiting	5.8	0.79	>99	5.3	13.	9.6	13.	6.8	0.94	>99	7.2	17.	11.	22.	6.3	0.82	>99	5.2	15.	10.	14.
East Poplar-IB																					
Threshold	2.7	0.72	>99	2.2	6.8	5.3	5.3	2.9	0.82	>99	2.6	8.6	5.6	8.0	3.0	0.77	>99	2.1	12.	5.0	5.8
Limiting	5.4	0.72	>99	4.3	14.	11.	11.	5.9	0.82	>99	5.3	17.	11.	16.	6.1	0.77	>99	4.2	23.	10.	12.
East Poplar-Scobey																					
Threshold	2.3	0.66	>99	1.4	8.8	4.0	3.7	3.5	1.0	>99	2.5	13.	6.4	6.3	2.2	0.72	>99	1.4	14.	4.5	3.4
Limiting	4.5	0.66	>99	2.8	18.	7.9	7.4	7.0	1.0	>99	5.0	26.	13.	13.	4.4	0.72	>99	2.8	29.	8.9	6.7
Middle Fork-IB																					
Threshold	3.4	0.91	>99	2.8	9.7	5.6	7.1	3.4	0.93	>99	2.5	10.	5.6	6.3	2.6	0.82	>99	2.1	12.	5.6	3.9
Limiting	6.9	0.91	>99	5.6	19.	11.	14.	6.8	0.93	>99	5.0	20.	11.	13.	5.1	0.82	>99	4.2	24.	11.	7.8
Middle Fork-Scobey																					
Threshold	2.2	0.63	>99	1.6	9.4	5.1	3.3	3.6	1.0	>99	3.1	13.	6.4	5.9	2.5	0.81	>99	1.8	16.	5.9	3.6
Limiting	4.4	0.63	>99	3.3	19.	10.	6.7	7.1	1.0	>99	6.3	26.	13.	12.	5.0	0.81	>99	3.6	33.	12.	7.3
West Fork-IB																					
Threshold	2.0	0.53	>99	1.7	13.	5.8	2.9	4.5	1.1	>99	5.1	19.	13.	7.1	2.9	1.0	>99	3.0	28.	8.8	3.6
Limiting	4.0	0.53	>99	3.3	25.	12.	5.9	9.1	1.1	>99	10.	38.	26.	14.	5.8	1.0	>99	6.0	56.	18.	7.3
West Fork-Bredette																					
Threshold	3.6	0.82	>99	3.6	16.	12.	4.7	4.1	0.93	>99	5.1	25.	17.	5.7	3.2	0.87	>99	3.6	32.	16.	3.9
Limiting	7.1	0.82	>99	7.1	32.	24.	9.3	8.3	0.93	>99	10.	50.	33.	11.	6.5	0.87	>99	7.1	65.	31.	7.7
Poplar-Bredette																					
Threshold	2.1	0.64	75.	1.4	10.	4.9	3.2	2.4	0.87	100	2.2	14.	6.1	5.2	2.3	0.83	94.	1.6	17.	5.0	3.5
Limiting	4.2	0.64	>99	2.8	21.	9.7	6.3	4.9	0.87	>99	4.4	28.	12.	10.	4.7	0.83	>99	3.2	34.	10.	7.1
Poplar-Poplar																					
Threshold	2.0	0.65	13.	1.7	9.4	5.0	2.7	2.6	1.0	38.	3.2	17.	9.8	4.7	2.3	0.86	19.	1.8	20.	6.3	3.1
Limiting	3.9	0.65	25.	3.4	19.	10.	5.4	5.2	1.0	75.	6.4	34.	20.	9.4	4.5	0.86	37.	3.6	40.	13.	6.2

one, and no samples were collected from the Poplar Basin with DS levels in excess of its threshold (and limiting) values (Table 8). In addition, the maximum concentration of DS (2420 mg/l) obtained from the streams was found to be well below the recommendation of the Environmental Studies Board (1973), which was set at 3000 mg/l. On the basis of DS, therefore, the various Poplar waters, including the accessory small streams and Fife Lake, should be "very satisfactory" for the watering of all stock animals, including the more sensitive poultry forms, and only "temporary effects, if any (24)", would be expected from this application. With respect to the common constituents, therefore, the Poplar Basin appears to afford a generally good quality of water for livestock consumption, although the high bicarbonate concentrations and the high summer pH levels of the streams would tend to detract from this quality to some extent. The basin's waters are most suitable for this use during the spring season as a result of the high flows and the associated dilutions that occur at this time.

On a basin-wide basis in Montana, the L/DS data in Table 65 indicate that median low flow increases in DS on the order of 2.0 to 3.4 might be tolerated without any significant degradations of the Poplar streams for stock watering purposes. In addition, DS increases between 3.9 and 6.9 would be required to reach the limiting levels of salinity. In relation to the East Poplar-middle Poplar-lower Poplar reach sequence which will be directly influenced by the Coronach development, these low flow L/DS values stand at 2.9-3.1 and 5.8-6.3 (winter versus summer) for the upstream reach near Coronach, and a distinct and consistent downstream decline in L/DS was observed with values of 2.0-2.3 and 3.9-4.5 near the Poplar's mouth because of the down-drainage salinity increases in the basin. The results from various water quality modeling efforts in the Poplar Basin will be required to establish whether or not such factor increases in dissolved solids and the other ions, as listed in Table 65, might be feasible in the drainage relative to the potential impact sources associated with the Coronach power generation facilities, e.g., the concentrating effects of the flow-through cooling system of the power plant.

Nutrients, metals, and other constituents.

Of the several water quality parameters summarized in the "nutrient and other constituents" tables of this report, e.g., Table 63, silica and COD (and TOC) can be viewed as non-affecting factors relative to the use of a water by domestic animals. The three combined nitrogen species, ammonia, total phosphorus, and orthophosphate also appear to be noncritical variables in terms of directly affecting stock animals since no reference criteria have been established for these parameters (16, 24, 41, 48, 114). Although the consumption of extremely high nitrite (greater than 10 mg N/l) and high nitrite-nitrate (greater than 100 mg N/l) waters can cause livestock fatalities (24), the critical levels of these variables were well above the concentrations that have been assessed for the Poplar streams (typically less than 0.8 mg N/l). Thus, NO_XN also appears to be an unimportant variable in the study region in relation to stock watering. However, the critical nutrients in a water, including NO_XN, can have an indirect effect on livestock when in much lower concentrations than 100 mg N/l by causing stream eutrophy at 0.9 mg N/l, given the occurrence of 0.1 mg P/l (68), and this in turn could lead to the development of toxic algae blooms. Such blooms can develop in Montana as evidenced by the recent Hebgen Lake bloom that killed several cows (and dogs)

that were consuming the lake's waters (102). But except for the upper East Poplar drainage, the nitrogen and phosphorous nutrient concentrations in the Poplar Basin were not at adequate levels to point to the levels of eutrophy that would be required to produce these blooms. In the case of the upper East Poplar, nutrient levels were only suggestive of a possibility for eutrophic conditions, and the chlorophyll data that has been collected from the stream did not demonstrate adequate algal densities to be suggestive either of stream eutrophy or of the occurrence of algae blooms. Thus, such indirect effects on stock animals from the nutrient species would appear to be unlikely for the Poplar region, at least with respect to its present level of nutrient enrichment.

In contrast to orthophosphate, fluoride and boron can have direct and adverse effects on stock animals, but no samples were obtained from the Poplar drainage with these constituents in excess of their reference criteria (Table 8). As a result, fluoride and boron, with maximum basin concentrations of 1.0 and 4.1 mg/l respectively, might also be graded as non-affecting factors relative to the use of a water by livestock. With respect to iron, no definite reference criteria have been established for this metal, although it has been recognized that iron can be toxic to livestock in exceedingly high concentrations while interfering with these animal's phosphorous metabolism (114). In addition, the intake of water by animals might be inhibited if the source is high in iron, and such reductions might have an ultimate effect on milk production (41, 48). "However, this should not be a common or serious . . ." difficulty in a general sense (24), and iron does not appear to be a problem for the Poplar drainage with its maximum dissolved and total recoverable concentrations in these streams reaching only 0.9 and 2.6 mg/l respectively during the low flow periods of the year. Thus, the several water quality variables summarized in Tables 20, 26, 30, 34, 37, 42, 45, 49, 53, 59, and 63 generally point to an excellent quality of water in the Poplar region for livestock applications.

While iron is typically a non-affecting factor relative to stock watering, many other metals can have quite drastic and toxic effects on stock animals even when in relatively low concentrations. These trace elements are listed in Table 8 along with their corresponding reference levels. In addition to these constituents, several of the unlisted trace elements might also have adverse effects, but similar to iron, these variables afford low order toxicities that require extremely high concentrations to be effective with such high concentrations generally uncommon in most aquatic systems. Examples of these trace elements and the possible affecting levels can be listed as follows: Be--nontoxic to about 6,000 mg/l (41); Mn--some effects at greater than 10 mg/l (41); Mo--concentrations at least greater than 20 mg/l required; and Zn--a 24 mg/l reference criteria (24).

The maximum total recoverable (TR) and dissolved (D) concentrations and the "typical" median values that were obtained for each of the trace elements from the various Poplar drainage analyses are summarized in Table 66. This table indicates that the high concentrations of Be, Mn, Mo, and Zn that would be required to affect stock animals were never assessed in samples from the Poplar system. But in a few other cases, the maximum TR concentration of a trace element did exceed the more stringent and corresponding reference criteria for livestock summarized in Table 8, i.e., Al, Hg, and possibly V. However, the maximum dissolved concentrations and the median TR and dissolved

Table 66. Maximum total recoverable (TR) and dissolved (D) concentrations in milligrams per liter of several trace elements obtained from samples collected from various streams in the Poplar River Basin; the "typical" median values of these constituents are also listed.

	Ag	Al	As	Ba	Be	Cd	Co	Cr	Cu	Hg
Maximum TR	<.04	8.1	0.05	0.2	0.01	0.02	<.05	<.05	0.18	0.015
Maximum D	--	0.05	0.027	--	0.01	0.001	--	0.01	0.009	0.0028
Median TR	<.04	0.33	<.02	0.1	<.006	<.002	<.01	<.05	<.01	<.0001
Median D	--	0.01	0.002	--	0.0	<.001	--	0.0	0.001	0.0

	Li	Mo	Mn	Ni	Pb	Se	Sr	V	Zn	Phenols
Maximum TR	0.15	<.10	0.53	0.100	0.100	<.01	0.58	<.11	0.29	--
Maximum D	0.22	0.004	0.20	0.006	0.005	0.0016	--	0.005	0.03	0.016
Median TR	0.10	<.10	0.06	<.02	<.03	<.01	0.55	<.05	0.01	--
Median D	0.11	0.001	0.01	0.003	0.002	<.0002	--	0.001	0.01	0.005

levels of the eleven, Table 8 trace elements (As, B, Cd, Cr, Co, Cu, Pg, and Se, plus Al, Hg, and V) were always well below their particular reference values for stock animals. The data in Table 66, therefore, describes a general absence of these types of water quality problems from the Poplar Basin. Other trace elements that have been analyzed in the Poplar drainage collections but for which no livestock toxicity information are available (16, 24, 41, 48, 114) would include Ag, Ba, Li, Ni, and Sr. As indicated in Table 66, it might be assumed that the concentrations of these elements were also too low to afford water quality degradations relative to livestock watering.

A few of the samples collected from the upper Poplar Basin were also analyzed for phenols and for certain of the pesticides. As indicated in Table 66, some levels of phenols were typically detected in these collections with the phenolic compounds most likely derived from natural sources (33). But no adverse effects on stock watering are anticipated for this constituent since Heller and Pursell (1938) have shown that appreciable concentrations of phenol are nontoxic to animals. In contrast, the pesticides can have more pronounced effects than the phenols on stock animals as summarized by the Environmental Studies Board (1973). However, although certain of the pesticides have been detected in the Poplar samples (lindane and 2,4-D) with their concentrations typically between 0.001 and 0.08 micrograms per liter, the critical limits that have been established for these contaminants were typically greater 0.1 ug/l, and the reference criteria specifically developed for lindane and 2,4-D stand at 5 ug/l and 2 ug/l respectively (24). This discrepancy between the empirical and the reference indicates that these chemicals, like phenol, were probably noncritical relative to the use of the basin streams for livestock applications. As observed for the stream's fishery, the pesticides were not at adequate levels to adversely affect any of the livestock consuming the Poplar waters or to significantly degrade any of the products that might be derived from these animals.

Irrigation

General features and field parameters.

As indicated in Table 4, irrigated agriculture is the major user of water in the Poplar River Basin, although this application represents only about 7% of the total flow of the drainage near its mouth in an average water year. This relates to the fact that the Poplar Basin is primarily a dryland farming area at the present time with less than one percent of the acreage in the region devoted to irrigation (54). However, other lands in the study area are purported to be irrigable, and additional acreages devoted to this pursuit are forecast for the near future (11, 56), entailing further water withdrawals from the system. Some attention, therefore, should be given to the present status of water quality in the drainage streams relative to their value for irrigational applications, in this case as applied primarily to hay and pasture grasses. In addition, some consideration should also be given to the possible effects of the Coronach development on this water use. About 2600 acres in the basin are irrigated from the East Poplar-middle Poplar-lower Poplar reach sequence in Montana, utilizing 3221 AF of water per year, and these lands will be directly affected by this development with the more noticeable effects occurring in an up-drainage direction from Poplar to Coronach (Figure 1). About 600 of these acres in Montana are irrigated via gravity, pumping, and spreader dikes directly from the East Poplar River which will also service the Coronach facilities, and these acres thereby will bear the brunt of any water quality impacts that are developed from the power generating station in Saskatchewan.

For most practical purposes, the various "field" parameters, excluding specific conductance and dissolved solids, are generally unsuitable for the quality evaluations of irrigation waters. These variables, when they are at their natural concentrations or typical levels, might be viewed as non-affecting factors relative to this water use, although the extreme values of some of these variables might have certain adverse effects on irrigation applications. However, the data that is necessary to quantify these requisite extremes and to develop specific reference criteria are not now generally available for these types of parameters. Obvious examples would include temperature and biochemical oxygen demand (BOD).

In the case of water temperature, excessively " . . . high or low temperatures in irrigation water can deter plant growth (48)." But a review " . . . of research accomplishments does not offer guidelines for establishing temperature criteria for irrigation waters (48)." As described by the National Technical Advisory Committee (1968), and with all other considerations being equal, " . . . a desirable range of temperatures would be from 55 to 85 F (12.8 C to 29.4 C)."

With respect to the Poplar Basin, the low winter temperatures of the streams, even though they were typically well below 12.8 C, would not be an affecting factor relative to irrigation since the drainage waters are not utilized for this purpose during the cold weather period of November to February. As indicated in Tables 18, 40, 47, and 57, temperatures were also found to be below this value on a fair number of occasions during the spring runoff season when the first irrigation applications are often made in the region (62), and this variable, thereby, might be representative of a short-

lived influential factor on irrigation at this time of the year. Temperature data collected by the Montana Department of Fish and Game (91) and the temperature data summarized by Aagaard (1969) indicate that about 59% of the days during the months of April and May had temperatures in the various Poplar streams below 12.8C with an average water temperature through these months of about 10.8C. Such low temperature restrictions would be much more severe during the month of March when the streams were most commonly near freezing conditions. But during the irrigation-intensive, summer season (June to October), temperatures of the basin's surface waters were much less frequently below this minimum reference value with such low temperatures, therefore, less suggestive of irrigation problems during these particular months than during the spring season. In addition, the higher temperature values outside of the desirable irrigation range (above 29.4C) are also unsuggestive of irrigation difficulties in the Poplar drainage since temperatures in excess of 29.4C were only very rarely obtained from the streams during the warm weather period (in 0.1% of the readings). In the main, the temperatures of the Poplar waters were within the desirable range of this variable for irrigation applications during the appropriate months of the year, and as a result, temperature does not appear to be a major problem parameter relative to the use of the Poplar Basin streams for irrigation purposes.

The BOD of an irrigation water, when in high concentrations, might also have some adverse effects on this particular water use. The availability of sufficient oxygen in a soil is a major requisite for optimum root development and plant growth. "Soil aeration and oxygen availability normally present no problem on well-structured soils with good quality water. Where drainage is poor, oxygen may become limiting. Utilization of waters having high BOD or COD (and TOC) values could aggravate the condition by further depleting available oxygen and produce reducing conditions in the soil (48)." This latter condition could in turn cause the release of toxic metals that were previously bound to the soil particles. However, little specific information is available concerning the use of high BOD waters for irrigation and their effects on plant growth (48). But in view of the generally high dissolved oxygen concentrations and the low BOD, COD, and TOC levels of the Poplar streams during the irrigation season, any impedance of soil aeration with the associated release of toxic metals, which could produce a retardation of root function and plant growth, seems highly unlikely relative to the use of the basin's waters for irrigation applications. Thus, DO, BOD, COD, and TOC are unsuggestive of water quality problems in the drainage in terms of plant watering. Of the several "field" parameters, a more likely source of trouble in this respect resides in the streams' high pH levels that were developed during the summer season.

In those portions of the western United States that have a predominantly alkaline-type of soil, waters with a low pH are most suited for irrigation (41). Wilcox (1948) claims that waters having a pH over 9.0 are unfit for this use. However, the exact effects of pH depend upon the crops to be grown and the type of soil in an area. The National Technical Advisory Committee (1968) suggests that streams with pH in the range 4.5 to 9.0 should present no insurmountable difficulties for this application. The Poplar Basin did produce some samples during the major irrigation period of the year (June to October) with pH's in excess of the upper limit of this range. Of the basin streams, Girard Creek (Table 32) was most distinct in this regard and

suggestive of a poor irrigation water. Fortunately, only 9% of the June to October collections from the Montana section of the drainage had pH in excess of 9.0 with none of the spring samples falling into this category, and none of the basin samples had pH in violation of the 4.5 lower limit. As a result, pH is best graded as a sporadic and relatively mild water quality problem from its "high end" in most segments of the Poplar drainage, at least with reference to the use of these streams for irrigation. However, some degradations in this regard might be anticipated, particularly if the high pH occurrences should happen to bracket a long series of consecutive days, and any further overall increases of pH during the summer season would certainly be an unfavorable development for this particular agricultural use in addition to degrading the value of the streams for stock animal watering.

Suspended solids and colloidal matter, when in high concentrations in a stream, are similar to BOD in having potentially adverse but generally unquantified effects on irrigation under certain conditions. Like the case for sodium, the major direct effect of the colloids and sediment in an irrigation water is most commonly directed to the soil. But the use of high colloidal-high suspended sediment waters for sprinkler applications can also produce some direct effects on the crops, and this use can result in the deposition of these materials on the plants, producing films, which could deter the plants' photosynthetic activities and reduce their rates of growth while also lowering their aesthetic appeal (24). In surface irrigation, the suspended solids of a water, particularly when high in the colloidal and clay fractions, could cause crust formations on the soil which would reduce seedling emergence, slow root aeration, and impede the infiltration of water into the soil; this latter feature, thereby, retards irrigation efficiency and also slows the leaching of salts from saline soil systems (48). But conversely, the National Technical Advisory Committee (1968) points out that " . . . sediment high in silt may improve the texture, consistence, and water-holding capacity of a sandy soil."

With respect to the Poplar Basin, the detrimental effects of irrigating with a high suspended solids water would seem to be more probable than gaining any beneficial aspects from this application in view of the fact that this region's major irrigated soils have a slow to moderate permeability and a more clay than sandy structure (Table 1). However, this type of problem does not appear to be likely for the Poplar drainage since the turbidity and suspended sediment levels of its streams were generally quite low (e.g., Tables 51 and 55). In addition, the low color readings that were typically obtained from the streams (Tables 17, 28, and 32) were unsuggestive of a high colloidal content. The only exceptions to these generally low turbidity and low color values were typically developed during the short-lived high flow periods which represented only a very small percentage of the year.

The discharge of a stream, of course, can afford some obvious volume restraints relative to its value as a source of water for irrigation. In the Poplar drainage of Montana, such low flows would be most restrictive for this application in the upper reaches of the three major forks, particularly the upper West Fork, and also in the various small tributaries, and it would be least restrictive in the Poplar mainstem below Scobey with its greater amounts of flow. But since irrigation is relatively undeveloped in the study region at the present time (11), stream discharge does not now appear to be a

major problem in the drainage, outside of the natural variations, with the irrigation diversions currently accounting for only a small percentage of the average yearly flows in the various basin streams as follows: East Poplar drainage in Canada--1.6%, Middle Fork drainage in Canada--0.4%, West Fork drainage in Canada--0.6%, East Poplar drainage above Scobey--4.0%, Middle Fork drainage above Scobey--9.1%, West Fork drainage above Bredette--4.2%, Poplar drainage above Bredette--11.8%, and the Poplar drainage above Poplar--7.4%. However, if these diversions are considered only in relation to the June-October flows of the streams while ignoring the spring runoff period, potential water conflicts in the region become more real. In addition, water conflicts (quantity and quality) between the agricultural, industrial, municipal, and instream uses and needs of the basin's waters will undoubtedly become more intense in the near future.

The coliform data in the various "field" parameter tables of this review have no direct application to the irrigation evaluations of the study area's waters. Although " . . . some plant pathogens . . . can survive and be transported in irrigation water . . . (48)," no information of this kind is now available for the Poplar Basin. "In general, the danger of spread of plant pathogens in irrigation water is so slight that it is usually ignored (48)." This same approach has also been applied to the study basin of this particular inventory.

Dissolved solids-salinity.

In contrast to suspended sediment and BOD, the salinity characteristics of a stream, i.e., its dissolved solids and specific conductance levels, play an obvious role in establishing its value as a source of irrigation water, and the unusable high extremes of salinity for this water application have been more definitely quantified than the extremes of the other "field" parameters. To a large degree, waters with DS and SC levels below 350 mg/l and 500 umhos per cm might be viewed as ideal for this agricultural use, assuming no other affecting factors, with these waters applicable to almost all crops under all conditions. At the opposite pole, waters with DS and SC levels above 2000 mg/l and 3000 umhos per cm are generally unsuitable for most irrigation purposes (57, 63). The various streams of the Poplar drainage generally fall between these two ends in having waters that are not ideal for irrigation while not being totally unsuitable for this use either with their DS and SC values well below these maximum values. Based on the classification system outlined earlier in this report for salinity as developed by the United States Department of Agriculture (Richards, 1954), the mean and median SC levels of the Poplar waters point to a high salinity hazard for irrigation during the intensive-use, summer season regardless of the streams' flow. However, some of the summer samples did demonstrate lower levels of SC that were indicative of a medium hazard while a few of the collections from the East Poplar were also suggestive of a very high salinity problem. These latter samples were probably obtained in conjunction with the spills from Fife Lake that were briefly alluded to previously in this review. In addition, some of the smaller basin streams and Fife Lake per se also revealed a very high hazard (Table 61). But for the most part, the Poplar waters demonstrated a high salinity hazard during the warm weather season that is suitable for those crops having good to moderate salt tolerances on well-drained soils with good to moderate permeabilities (57, 63).

The mean and median SC levels of all the major Poplar streams during the spring season were also suggestive of a high salinity hazard for irrigation during the low flow stages of this particular period. As a result, these waters would have an identical irrigation application in terms of crops and soils as described previously for the summer months. During the high flows of spring, however, the waters in the upper portions of the drainage demonstrated lower mean and median SC values and a medium salinity hazard which is indicative of a better quality for this agricultural use. But in the Poplar mainstem below Scobey, the waters generally retained their high salinity rankings in spite of the increases in stream discharge. Nevertheless, many of the streams did produce occasional samples during the high discharge periods that were indicative of a low salinity hazard. In general, therefore, the quality characteristics of the basin's waters were best suited for irrigation in an up-drainage direction and during the high flows of the spring season. But these instances of a better quality irrigation water during the spring months would appear to be relatively short-lived because of the brief duration of the high flow stages, and for most purposes, the salinity characteristics of the Poplar waters were generally quite similar among the various streams regardless of their geographic location and season. Thus, a high salinity hazard for irrigation seems to be the general rule for the study region.

Based on the typical DS and SC levels of the Poplar waters and their high salinity features, these streams apparently have a Class II-type of water for irrigation as summarized in Table 9. This class of water is quite variable in its potential value for irrigation, ranging from "good to injurious", and this variability is related to the types of crops that are to be grown and to the area's soil characteristics; the application of Class II waters could be "harmful under certain conditions of soil, climate, and management practices." As noted previously, however, these high salinity hazard waters should be "suitable for all tolerant and for many semi-tolerant (plant) species," assuming appropriate soil conditions. As indicated in Table 10, irrigable plants of this kind would include, most obviously, a few of the field crops, i.e., barley, sugar beets, and rape, and several of the forage species such as the wheatgrasses, wildrye, and tall fescue. In addition, several of the truck crops can also be added to this listing, e.g., beets, asparagus, and spinach, plus several of the other field crops--rye, wheat, oats, corn, flax, and sunflower. Some of the somewhat less salinity tolerant truck crops might also be placed, for the time being, into an irrigable classification for the Poplar Basin, e.g., tomato, cabbage, lettuce, sweet corn, and potato, with a large number of additional forage species also falling into this category, ranging from sweetclover and ryegrass in Table 10 to alfalfa, rye (hay), and wheat (hay). A successful application of the Poplar waters to these 21 forage, 9 field, and 11 truck species, therefore, might be expected, at least upon first consideration.

But these same Poplar waters would "not (be) suitable for most salinity sensitive species." Such plants would include all of the fruit crops potentially raised in the region (apple, boysenberries, blackberries, raspberries, and strawberries), a few of the truck crops (beans and radish), and some of the forage species which encompass several of the clovers plus foxtail and burnet. Other of the plant species listed in Table 10, but not mentioned above, are only slightly tolerant to salinity, and as a result, these plants are probably best placed in a borderline category relative to their irriga-

bility in the Poplar Basin. These species would include bell pepper, carrot, onion, peas, squash, and cucumber of the truck crops, plus several of the remaining forage species, e.g., oats (hay), blue grama, fescue, smooth brome, and sourclover, among others. Thus, 30 of the species listed in Table 10 appear to be generally non-irrigable with the Poplar drainage waters, and the Poplar region, thereby, affords a mixed blessing in relation to the suitability of its streams for this water use.

Of the 71 plants ranked in Table 10, alfalfa is the most commonly irrigated species on a commercial level in the Poplar Basin, although some irrigated acreages might also be devoted to wheatgrass, barley, and wheat (36). Fortunately, all of these plants, particularly barley and wheatgrass, are fairly tolerant to saline conditions (Table 10) which makes such irrigation applications from the Poplar streams feasible at the current salinity levels or DS concentrations of the various waters. As a result, most of the Poplar drainage streams probably have an adequate quality of water for the irrigation of hays and pasture grasses. However, some irrigation restrictions have been suggested by the Soil Conservation Service for the extreme low flow periods of the summer season, primarily September, because of the high salinity levels in the basin's surface waters at these times (62). With respect to the various non-forage crop plants listed in Table 10, any irrigation in this regard is probably a noncommercial venture and most likely performed on a private garden basis. Such private garden enterprises should also be successful in the study area if the appropriate types of crop plants, as described previously, are being watered from the basin streams at a suitable time of the year.

Based on median SC values, the major Poplar drainage streams would appear to be able to withstand a fairly significant increase in total salt concentrations before their high salinity hazard classification relative to irrigation is elevated to a very high salinity status. During the spring season, 1.90- to 2.05-fold increases in salinity might be tolerated in the East and Middle Forks of Montana even during low flow stages. For the West Fork in this same season, such allowable increases could be somewhat higher, 2.35- to 2.60-fold, although much lower increases would be tolerated in the Poplar mainstem below Scobey because of these segments' higher DS levels (between 1.75- to 1.90-fold). The required X-fold increases of salt or median SC that would be necessary to produce a very high salinity hazard in the Poplar streams during the irrigation-important summer season can be summarized as follows: upper East Poplar (Coronach and the IB)--1.80 to 2.00, lower East Poplar (Scobey)--1.35, Middle Fork--1.50 to 1.60, West Fork--1.65 to 1.90, Poplar mainstem (below Scobey)--1.35 to 1.45.

However, although a 1.3-fold increase in total salt content might not elevate a stream's salinity hazard to a very high level and might not make its waters totally unsuitable for irrigation applications, the National Technical Advisory Committee (NTAC) (1968) points out that between the range of 500 mg DS/l and 2000 mg DS/l " . . . the value of the water appears to decrease as the salinity increases." Since the DS concentrations of the Poplar streams are typically found within these limits, any increases of salinity in the Poplar Basin waters would, according to this observation, degrade the value of these waters for irrigation. In essence, the Poplar drainage might be viewed as a borderline system for irrigation applications, and any salinity impacts derived from the Coronach development or from other sources

would certainly impair this agricultural use to some extent. The above listed X-fold factors, therefore, only delineate the maximum increases in salts that might be tolerated without totally negating the value of the Poplar waters for irrigation purposes. Certain adverse effects on irrigation should be expected at salinity increases much lower than those implied by these various factors.

As suggested by the NTAC (1968) observation and by the summaries in Tables 9 and 10, the influence of salinity on irrigation effectiveness can be best visuallized as a continuum rather than an "all or nothing" effect with different plants being influenced at different DS-SC levels depending upon soil conditions, climate, management practices, and the plant's particular salinity tolerances. Thus, irrigation evaluations are best made when they are site specific in nature, that is, when they specifically consider the irrigated plants and soils that characterize the region under consideration. The more generalized evaluation presented above indicates that the Poplar Basin's waters are probably suitable for the irrigation practices that are currently in vogue in the drainage. But a site specific evaluation will provide added confirmation for and further insights into this conclusion, and it will provide a better basis for making judgements relative to the magnitude of the salinity increases that might be tolerated in the basin without significantly degrading the current irrigation values of its streams.

Klages (1976) points out that such site specific evaluations for the Poplar drainage should be directed primarily to alfalfa since it is the most commonly irrigated plant in the region and one of the most sensitive of the irrigated species in the drainage to saline conditions (Table 10). He also indicates that the slow to moderate permeabilities of the major irrigated soils in the study area (Table 1) should also be considered in this evaluation. Assuming a soil leaching requirement of 20-25% for the study region, Klages (1976) made the following specific recommendation for continuous and supplemental irrigational reference criteria for the Poplar drainage: "Average value should not exceed electrical conductivity of 1.5 mmhos/cm (1000 ppm) for continuous irrigation. For supplemental irrigation (where natural precipitation supplies much of the water used by the plant) the average electrical conductivity could be as high as 2.0 (1300 ppm) especially if used with a high level of management (36)."

The NTAC (1968) also recommends a salinity (SC) value for irrigation at 1500 umhos (or 1000 mg DS/l) in order to avoid any "adverse effects on many crops" unless "careful management practices" are utilized in those agricultural areas with higher salinity waters. The Environmental Protection Agency (1976) has also adopted this same criteria. Table 67 summarizes the DS-SC characteristics of various streams in the Poplar drainage for comparison to this reference value. Based on this salinity data, the Poplar Basin, during the spring season, appears to have a generally good quality of surface water for continuous irrigation since the mean and median DS-SC levels of the various sampling stations were typically well below their site specific reference criteria at this time. The unnamed creek feeding the Coronach town reservoir affords a major exception, and as indicated in Table 61, such small drainage streams and accessory waters apparently have a poor quality of water for irrigation as a general rule. Of the other streams, only 11% and 5% of the samples collected from the drainage through the spring period had their DS and SC levels in excess of the corresponding irrigation ref-

Table 67. Salinity characteristics of the major Poplar Basin streams expressed as their mean, median, and maximum dissolved solids concentrations (mg/l) and specific conductance levels (umhos per cm at 25C) by irrigation season (IB--international boundary). The values that exceed the site specific reference criteria for irrigation (1000 mg DS/l and 1500 umhos SC/cm) are denoted by an asterisk.

	Spring Low Flow			Spring High Flow			Summer Low Flow			Summer High Flow		
	Mean	Medium	Maximum	Mean	Median	Maximum	Mean	Median	Maximum	Mean	Median	Maximum
Unnamed Creek-Coronach												
Dissolved Solids	1186*	1200*	1260*	--	--	--	1042*	1035*	1181*	--	--	--
Specific Conductance	1399	1370	1520*	--	--	--	1459	1423	1800*	--	--	--
Girard Creek-Coronach												
Dissolved Solids	613	617	670	--	--	--	641	645	718	339	365	454
Specific Conductance	819	823	1015	--	--	--	1029	1040	1280	506	525	620
East Poplar-Coronach												
Dissolved Solids	685	732	988	354	338	661	807	794	1507*	--	--	--
Specific Conductance	897	915	1325	508	500	851	1116	1140	1525*	--	--	--
East Poplar-IB												
Dissolved Solids	784	850	1145*	425	405	1116	940	826	2252*	1366*	1454*	1790*
Specific Conductance	1074	1100	1450	673	618	1325	1369	1245	2300*	1850*	2056*	2410*
East Poplar-Scobey												
Dissolved Solids	756	712	938	--	--	--	1188*	1140*	1530*	1163*	875	1745*
Specific Conductance	1113	1140	1200	--	--	--	1726*	1696*	2250*	1594*	1360	2112*
Middle Fork-IB												
Dissolved Solids	779	740	900	--	--	--	985	971	1410*	--	--	--
Specific Conductance	1210	1180	1350	--	--	--	1451	1440	2000*	--	--	--
Middle Fork-Scobey												
Dissolved Solids	737	701	1104*	580	577	630	957	1007*	1130*	623	623	1012*
Specific Conductance	1071	1115	1320	848	836	1100	1461	1495	1700*	783	783	1173
West Fork-IB												
Dissolved Solids	534	551	809	--	--	--	814	858	1100*	--	--	--
Specific Conductance	844	870	1250	--	--	--	1265	1330	1600*	--	--	--
West Fork-Bredette												
Dissolved Solids	643	606	861	357	374	497	766	770	882	614	614	915
Specific Conductance	962	950	1150	494	510	720	1175	1195	1650*	852	852	1066
Poplar-Bredette												
Dissolved Solids	996	1023*	1370*	512	608	786	1019*	1070*	1150*	1175*	1342*	1480*
Specific Conductance	1194	1270	1500	780	990	1150	1514*	1560*	1710*	1695*	1775*	2200*
Poplar-Poplar												
Dissolved Solids	883	955	1000	767	759	902	1153*	1100*	1870*	834	784	1144*
Specific Conductance	1238	1205	1560*	1188	1100	1420	1743*	1625*	3180*	1176	1179	1550*

erence values with a maximum basin salinity for this season on the order of 1370 mg/l and 1560 umhos. Thus, the March-May waters of the Poplar region might be graded as excellent for supplemental irrigation. Of the salinity violations, most were obtained during the low flows of the spring months and in the Poplar mainstem below Scobey.

However, Table 67 also indicates that significant quality degradations for irrigation do become evident throughout the basin during the summer months, and about 40% and 37% of the water samples collected during the low flows of the June-October period had DS and SC in excess of the site specific reference criteria respectively (36). Such violations were also quite common during the higher flows of the summer season (in 42% and 32% of the collections), and they were most distinct in the lower East Poplar River near Scobey and in the Poplar mainstem below Scobey where 100% and 66% of the samples had DS concentrations greater than 1000 mg/l respectively and where 88% and 87% of the samples had SC levels greater than 1500 umhos. For the rest of the major streams, these warm weather DS and SC percentages can be listed as follows: the upper East Poplar drainage--12% and 4%, the Middle Fork--44% and 44%, and the West Fork--5% and 8%. These percentages suggest that the West Fork probably has the best quality of water for irrigation in the Poplar drainage, outside of the upper East Poplar, whereas the summer applications of water from the lower East Poplar-Poplar mainstem reaches would appear to be somewhat marginal in nature.

The high maximum summer DS-SC levels that were obtained for some of the streams were well above the irrigation reference criteria, and this feature coincides with the Soil Conservation Service recommendation (62) that the Poplar drainage waters should not be utilized for irrigation during certain phases of the warm weather period. Although the site specific recommendation of Klages (1976) would indicate that the Poplar Basin has a generally excellent quality of water for supplemental irrigation during this period, some of the basin streams even exceeded these upper criteria (1300 mg/l or 2000 umhos per cm) on occasion during the months of June to October pointing to the occurrence of sporadic problems in this respect. The high salinity maximums obtained from the East Fork and Poplar mainstem, particularly those during the summer high flow periods, were probably related to the spills from Fife Lake, and these data were suggestive of a very poor quality of water for irrigation purposes.

In relation to the use of the drainage streams for continuous irrigation during the summer season, Table 67 indicates that the major forks should have an adequate quality of water for this application since their mean and median DS-SC levels at this time were generally below the corresponding site specific reference criteria. The major exception would include the lower East Poplar near Scobey which had statistical DS and SC levels between 11% and 15% higher than the reference values during the warm weather period. In addition, the salinity characteristics of the Middle Fork waters were very close to reducing its suitability for continuous use (generally within 0.2% to 4.5% of the reference levels). These features also indicate that the upper East Poplar drainage and the West Fork probably provide the best sources of water in the study region for repeated plant waterings. The amenability of the major Poplar streams in this respect can be additionally ranked as follows: (1) Girard Creek-Coronach, (2) East Poplar River-Coronach, (3) West Fork-FBB, (4) West Fork-IB, (5) East Poplar-IB, (6) Middle Fork-IB, (7) Mid-

dle Fork-Scobey, (8) unnamed creek-Coronach, (9) main Poplar-Bredette, (10 East Poplar-Scobey, and (11) main Poplar-Poplar.

Similar to the lower East Poplar, the Poplar mainstem below Scobey also had waters with the mean and median DS-SC levels of the summer season typically above the reference criteria for continuous irrigation. This was most distinct in the extreme lower reach of the Poplar near Poplar with values between 8% and 17% higher than the site specific reference levels; percentages between 0.8% and 8% were obtained for the middle, Bredette segment. These features in turn would suggest that while the waters in the upper East Poplar River and the West Fork appear to be of a good quality for this agricultural use, those in the lower East Poplar and the Poplar mainstem, and probably in the Middle Fork and the small unnamed creek, are certainly of only a fair and borderline quality at best in relation to their suitability for continuous applications during the warm weather months. Such fair qualities might be anticipated in view of the high salinity hazard ranking that has been given to the basin. But as noted, their qualities at this time would seem to be generally excellent for supplemental irrigation purposes since the mean and median DS-SC levels of all the major streams were well below 1300 mg/l and 2000 umhos per cm during the months of June through October.

This tendency towards only a fair warm weather irrigation quality in some of the Poplar Basin streams is further illustrated by the somewhat high yield reductions that might be expected for certain of the crops after their irrigation with these waters. Assuming a 22% leaching requirement for the Poplar soils plus an adequate irrigational application of the streams' waters to these soils (36), the potential average yield reductions in the case of the most commonly irrigated species in the basin (alfalfa) can be listed as follows: upper East Poplar drainage--20% to 26%, West Fork--27% to 32%, East Poplar-IB--35%, Middle Fork--38%, middle main Poplar--40%, lower East Poplar-Scobey--48%, and lower main Poplar--49%. Using calculated values for the specific conductance of the soil solutions after irrigation, these percentages were taken from yield reduction information compiled by the NTAC (1968); the average specific conductance of a soil solution (SC_D) relative to each stream application was calculated by using the leaching requirement (LR) equation presented earlier in this report. Such calculations, of course, also indicate that the average yield reduction of alfalfa would be lower during the spring period, e.g., 30% in the case of the Poplar near Poplar, than during the summer because of the lower salinity levels of the drainage streams during these runoff months. Yield reductions would also be lower in the summer for the more salinity tolerant plants, such as the wheatgrasses, than for alfalfa, e.g., a 10% reduction for crested wheatgrass using the lower Poplar waters, but they would be higher for the more salinity sensitive species such as corn and potato which showed 73% reductions with waters from this same reach. A more striking example of such yield reductions resides in the clovers which demonstrated values in excess of 73% for all of the Poplar streams.

Yield reductions of 38% to 49% for alfalfa would appear to be illustrative of a reduced quality of water for irrigation use. But if such losses can be tolerated by the agriculturists in the region, then the lower East Poplar, the Middle Fork, and the Poplar mainstem might be judged as having a fair quality of water for this agricultural application relative to its site specific reference criteria. By comparison, waters in the West Fork

and upper East Poplar, with yield reductions between 20% and 35%, would then be rated as having a good quality in this regard. But if these percentage losses in yield cannot be readily tolerated by the area farmers, then the various Poplar streams are probably best graded as having either a poor or a fair quality of water for this use with the better qualities ranging in an up-drainage direction. The deciding factor on whether or not to irrigate with these streams would be the development of a potential net gain in production from the irrigated over the dryland fields regardless of the yield reductions that might be obtained from this practice relative to some theoretical minimum reduction using low salinity waters. Critical to this decision would be the point where the dryland production of a crop is greater than its theoretical irrigated production minus the salinity-caused reductions in yield that might occur as a result of using the Poplar waters for irrigation. For alfalfa (and wheatgrass, barley, and wheat), this relationship is probably to the positive side for the Poplar Basin at the present time; for the clovers (and corn and potato), a negative value might be anticipated for this expression.

As indicated previously, the Poplar streams will be able to withstand considerable quantities of salt additions before their high salinity hazard rankings are elevated to very high levels (57), which would then make the streams largely unsuitable for most irrigational uses, i.e., factors on the order of 1.35- to 2.6-times depending upon stream and season. As suggested by the previous discussions however, much smaller salt increases than those implied above would certainly have many adverse effects on this water use. During the spring season with its comparatively low DS concentrations, somewhat high salinity increases might be tolerated in the basin without degrading the Poplar waters for continuous irrigation to any significant degree. Such possible increase factors for the various streams, calculated as the site specific DS-SC reference criteria divided by the mean and median DS-SC levels of a sampling station, can be listed as follows: Girard Creek--1.6, East Poplar-Coronach--1.4, East Poplar-IB to Scobey and the Middle Fork--1.2 to 1.4, West Fork-IB--1.7 to 1.9, West Fork-FBB--1.5 to 1.7, Poplar mainstem--<1.0 to 1.3, and the unnamed creek-Coronach--<1.0 to 1.1.

But for the warm weather season of June to October with the associated salinity degradations that occur during these months, significant salt accruals of the magnitude described for the spring period would certainly be ill-advised, and only slight increases in salinity at this time could make the waters of the drainage generally unsuitable for the types of irrigation practices that are currently in effect in the study area. For example, only a 25% or 1.25-fold increase in SC over the mean summer value of this variable would significantly increase the yield reduction of alfalfa from 49% to a value greater than 75% for this period. In addition, Klages (1976) points out that data " . . . summarized by the Water Quality Bureau shows dissolved solids and electrical conductivity already averaging about these (reference) levels leaving little room for increased salinity if irrigation is to continue." No summer increases in salinity are recommended for the lower East Poplar and the Poplar mainstem (plus the unnamed creek near Coronach and the other small basin streams) since the warm weather mean and median DS-SC levels of these streams were already in excess of the site specific reference criteria for continuous irrigation. In the case of the Middle Fork, only very slight increases of summer salinity of about 1.05-times would be required to cause these waters to exceed these criteria. For the remaining streams,

the following warm weather salinity enhancements might be tolerated for continuous irrigation: 1.44- to 1.56-fold increases for Girard Creek, 1.24- to 1.34-fold increases for the East Poplar River near Coronach, 1.06- to 1.21-fold increases for the East Poplar at the IB, 1.13- to 1.19-fold increases for the West Fork at the IB, and 1.26- to 1.31-fold increases for the West Fork near Four Buttes-Bredette.

Somewhat higher increases in total salts would be acceptable if the drainage waters were to be used only for supplemental irrigation during the summer, e.g., 1.38- to 1.60-fold increases for the East Poplar at the IB and 1.29- to 1.39-told increases for the Middle Fork. But in the main, the Poplar River Basin might be best viewed as having a borderline-type of water quality for irrigation, and any warm weather salinity enhancements in the system, as might result for the Coronach development, much over the ratios listed above (between 1.05 and 1.34) would certainly have adverse effects on the value of the region's waters for this agricultural application.

Common constituents--direct plant effects.

Some of the variables summarized in the several common constituent tables for the various sampling sites (e.g., Tables 24, 41, 48, and 58) might be viewed as non-affecting factors in relation to the irrigational use of a water. Total hardness and carbon dioxide would most obviously fall into this category. In addition, carbonate, total alkalinity, phenolphthalein alkalinity, and calcium also can be considered in this manner since no affecting concentrations of these variables have been identified by various authorities for irrigation (16, 24, 41, 48, 114), outside of contributing to the salinity status of a water. Total alkalinity and phenolphthalein alkalinity are generally not listed in the conventional chemical analyses of irrigation waters, and in the case of calcium, relatively high concentrations of this common ion are actually desirable for an irrigation water in order to insure a good permeability and tilth in the receiving soil (41).

For the remaining common constituents, two types of general influences might be visuallized in relation to irrigation--direct effects on the irrigated crop or forage species per se, and indirect effects on these plants by altering soil chemistry which in turn can adversely or beneficially (as the case with calcium) change the soil structure. SAR and %Na are derived parameters that pertain primarily to this soil aspect. The direct effects of a common constituent on an irrigated plant, in turn, can be either positive in a nutritional sense, i.e., beneficial when in appropriate concentrations, or they can be detrimental in a toxic sense when in too high of a concentration or detrimental in a nutritional sense when in too low of a concentration. As noted earlier in this report, the potentially adverse effects of an ion when in high concentrations will receive the prime consideration of this inventory, although some of the more obvious nutritional aspects of a few of the parameters will also be pointed out in association with the appropriate discussion.

With respect to the direct effects of the common constituents on the crop and forage plants, several of the other ions might also be viewed as insignificant factors for irrigation in the Poplar Basin because of their low concentrations in the drainage streams relative to the high levels that would be needed to have toxic or adverse effects on crop growth and yield.

In most instances, specific irrigation reference criteria have not yet been established for these constituents (16, 24, 41, 48, 114). Magnesium, potassium, and chloride are most readily placed into this grouping.

In the case of magnesium, concentrations on the order of 3000 mg/l are required to afford plant toxicities (41), and this critical value is far above the magnesium levels that have been obtained from any of the Poplar drainage streams. Based on the previous discussion, adverse salinity effects on many crops would be expected long before this extreme level of magnesium is actually achieved in a water. In addition, somewhat high concentrations of magnesium, as noted for calcium, are desirable for an irrigation water both from a nutritive standpoint, i.e., calcium and magnesium are essential for normal plant growth, and for the maintenance of a good soil tilth (41). In relation to potassium, some evidence suggests that high concentrations of this parameter might also be toxic to some plants (41), but a maximum level of potassium in the Poplar Basin of 67 mg/l with a more typically high value of only 26 mg/l certainly does not meet this high concentrational requirement. In turn, potassium, like magnesium, is also a macronutrient and has to be readily available in the soil solution for optimum plant growth. The concentrations of potassium that are evident in the Poplar waters thereby could be actually beneficial to irrigation in this respect.

In contrast to magnesium and potassium, chloride is not commonly viewed as a macronutrient, and it is " . . . considered to be among the most troublesome anions in irrigation water . . . (41)" with concentrations of chloride immediately above 100 mg/l reported to be harmful to certain plants. However, a major portion of the Poplar drainage is characterized by the low chloride concentrations of its streams which were well below this 100 mg/l level, and even the lower Poplar, which had comparatively high concentrations of this ion relative to the rest of the basin, had chloride levels typically below this value during the irrigation season (Table 58). Thus, chloride is not suggestive of a significant water quality problem on its own right relative to irrigation, and since chloride is not a critical macronutrient, its generally low concentrations in the Poplar streams should also pose no problems of this kind to this water use.

The listing in Table 9 is further illustrative of the apparently unimportant nature of chloride in this drainage. According to this table, the Poplar streams might possibly have a Class I ranking for irrigation on the basis of chloride since the concentrations of this constituent typically stood at less than one me/l for the waters above Poplar and at 1.1 to 3.6 me/l for the Poplar River near Poplar. These chloride values are well within the <2 to 5.5 mg/l range that defines the Class I category, and as a result, these streams could be "suitable (for irrigation) under most conditions." Of course the high DS levels of the streams generally negate this "excellent to good", Class I classification, and the chloride concentrations of the lower Poplar near Poplar also fit within the range that is specified for the Class II designation. In addition, the contribution of chloride to the "potential salinity" levels of the lower Poplar are definitely suggestive of some irrigation problems, as will be described later.

Bicarbonate can also have an adverse influence on irrigated crops per se when in high concentrations, but the effects of this ion are somewhat

indirect by causing an unavailability of iron to the plants (48). The major symptom of this occurrence is the development of a chlorosis in the leaves of the irrigated plants. Concentrations of bicarbonate in the vicinity 10 me/l to 20 me/l, depending upon other factors, are required to produce this condition, and the NTAC (1968) points out that this type of difficulty is generally of little concern in the field where the precipitation of calcium carbonate minimizes this hazard. In addition, the mean and median bicarbonate concentrations of the major Poplar waters during the low flows of the June-October period generally ranged from 7.0 me/l to 11.7 me/l, and these values were either well below or only slightly above the lower critical level of this constituent when problems of this kind might first begin to develop. Furthermore, a bicarbonate-induced iron unavailability would not be expected for the high flows of the spring season since bicarbonate concentrations at this time were generally less than 6.5 me/l. As a result of these various features, bicarbonate might be best ignored as a potential problem parameter in a direct sense in relation to irrigation applications from the Poplar streams, at least for the present time. However, if chlorotic leaf symptoms should become evident in the irrigated plants of the study region, particularly after the initiation of the Coronach power generating facilities, then the relatively high bicarbonate concentrations of the drainage streams might be considered as a possible causal factor. Of more concern to irrigation are the detrimental effects that bicarbonate can have on soil structure via the calcium carbonate precipitations.

Because of the high concentrations of sodium and sulfate in the Poplar streams, and because of the potential toxicities that these ions can have on crop plants when in high concentrations, sodium and sulfate would appear to have the greatest likelihood of the common ions for having some directly adverse effects on the irrigated plants of the Poplar Basin. But in the case of sodium, no specific irrigational reference criteria have been established for this ion (16, 24, 41, 48, 114). In one particular investigation, waters high in sodium (106 mg/l to 212 mg/l), when used for sprinkler irrigation, were found to produce deletrious accumulations of this ion in the foliage of certain plants, and this eventually caused the development of extensive leaf burns and a defoliation of the affected shoot systems (101). Since some of the concentrations of sodium in the Poplar streams generally fall within or above this range, this feature could be suggestive of problems in the study area in the case that sodium sensitive plants are being watered from these streams through the use of sprinkler systems.

In other research efforts (41), several sodium salts such as $NaHCO_3$, $NaCO_3$, NaCl, and $NaSO_4$ have been shown to have directly detrimental effects on various plants when waters high in these salts were used for surface irrigations. As summarized by McKee and Wolf (1963), the following statements might provide some insight into the types of salt concentrations that would be required to affect the irrigated plants: $NaHCO_3$--1500 mg/l of this salt has been reported to reduce the dry weight of tomatoes; $NaCO_3$--this salt has been purported to be extremely toxic to plants, although concentrations between 100 and 400 mg/l were shown to be non-injurious to a variety of greenhouse plants; NaCl--the effects of this salt are quite variable depending upon the plant species and climatic conditions, but it is recommended that water " . . . used for irrigation should not contain more than 700 mg/l of dissolved minerals in which sodium chloride predominates . . . "; $NaSO_4$--this salt has been found to be injurious to plants at a concentration of

4000 mg/l, although root growth and water absorption capacities were depressed at 710 mg/l.

As indicated by the above descriptions, relatively high concentrations of these four salts would be required to produce any deletrious effects on the irrigated plants, and in some cases, adverse salinity impacts might also be expected before the required level is achieved. Such high sodium salt concentrations have not been typically observed for the Poplar streams with the maximum mean or median concentrations of $NaHCO_3$, $NaCO_3$, NaCl, and $NaSO_4$ in the major basin waters during the low flow irrigation seasons observed as follows: $NaHCO_3$--1027 mg/l (East Poplar-Scobey, Table 24), $NaCO_3$--360 mg/l (Poplar-Poplar, Table 58), NaCl--467 mg/l (Poplar-Poplar), $NaSO_4$--693 mg/l (East Poplar-Scobey). However, a few of the samples that have been collected from various Poplar drainage streams did produce concentrations of these salts in excess of the levels that have been shown to be detrimental to irrigated plants; examples of this occurrence can be found in the maximum summer concentrations of the appropriate ions at the East Poplar-IB station and at the Poplar-Poplar site (Tables 19 and 58). In many cases, these high ionic concentrations were probably obtained in conjunction with the Fife Lake spills. But in the main, the concentrations of sodium and the associated anionic radicals in the Poplar drainage streams were not at adequately high levels to be suggestive of significant irrigation problems stemming from these various sodium salts.

In the case of sulfate, Kelly, et al (1939) have observed that the sulfate ions in themselves may be toxic to irrigated plants when in high concentrations in addition to causing a calcium precipitation (as $CaSO_4$) which could degrade the structure of a soil. Hinman (1938), in turn, has suggested that concentrations of this ion over 500 mg/l are hazardous to this water use, and Scofield (1935) developed the following classification system for irrigation waters in relation to their sulfate concentrations: excellent--<192 mg/l, good--192 to 336 mg/l, permissible--336 to 576 mg/l, doubtful--576 to 960 mg/l, and unsuitable-->960 mg/l (111). As a further refinement, Doneen (17), recognizing the potential toxicities of both sulfate and chloride on irrigated plants, developed the concept of "potential salinity" to describe the possible combined effects of these two ions on an irrigation system. As noted previously, his means of classification also takes into account a soil or leaching factor since these two ions will require a greater effective concentration in highly permeable soils than in soils that are poorly drained. Doneen's classification of irrigation waters and the expression that is utilized for calculating potential salinity values are summarized in Table 11. Potential salinity values that have been calculated for the major streams of the Poplar Basin are listed in Table 68. With reference to the soil classification system presented in Table 11, the irrigated soils of the Poplar region (Table 1) would probably have the following A, B, and C designations: Banks--undoubtedly a C-type of soil, Glendive--possibly a C-type of soil, Haverlon--probably a B-type of soil, and Lohler--most likely an A-type of poor quality soil.

In relation to the 500 mg/l irrigational criteria for sulfate (105), the Poplar drainage waters would appear to be suitable for this water use since sulfate concentrations in the streams were well below this reference value for a major percentage of the samples collected from the basin, and Scofield's classification system for sulfates is generally in accord with

Table 68. "Potential salinity" characteristics of the major Poplar Basin streams calculated from their mean, median, and maximum chloride and sulfate concentrations during each of the irrigation seasons (IB--international boundary). Potential salinity has been defined as the concentration of chloride plus one-half of the concentration of sulfate in milliequivalents per liter.

	Spring Low Flow			Spring High Flow		
	Mean	Median	Maximum	Mean	Median	Maximum
Unnamed Creek-Coronach	2.90	2.57	4.04	--	--	--
Girard Creek-Coronach	1.26	1.15	1.98	--	--	--
East Poplar-Coronach	1.39	1.48	2.73	0.76	0.67	1.78
East Poplar-IB	2.02	2.06	3.00	1.12	0.96	3.25
East Poplar-Scobey	2.34	2.25	2.79	--	--	--
Middle Fork-IB	2.24	2.24	2.67	--	--	--
Middle Fork-Scobey	1.86	1.84	2.44	1.07	1.07	1.18
West Fork-IB	1.24	1.13	2.04	--	--	--
West Fork-Bredette	1.26	1.19	1.74	0.83	0.68	1.69
Poplar-Bredette	2.80	2.77	3.58	1.99	2.03	3.54
Poplar-Poplar	3.18	2.75	5.60	5.09	5.09	6.41
(extreme high flows)				1.29	1.29	1.58

	Summer Low Flow			Summer High Flow		
	Mean	Median	Maximum	Mean	Median	Maximum
Unnamed Creek-Coronach	3.84	3.90	5.17	--	--	--
Girard Creek-Coronach	2.27	2.36	2.77	1.16	1.24	1.73
East Poplar-Coronach	2.12	2.09	3.69	--	--	--
East Poplar-IB	2.71	2.58	6.20	4.32	4.31	6.08
East Poplar-Scobey	4.26	3.94	5.45	3.62	3.15	4.92
Middle Fork-IB	2.62	2.71	3.73	--	--	--
Middle Fork-Scobey	2.99	3.24	3.78	1.12	1.12	1.75
West Fork-IB	1.89	1.89	2.55	--	--	--
West Fork-Bredette	1.61	1.64	2.09	1.18	1.18	1.70
Poplar-Bredette	3.70	3.68	4.49	2.69	3.15	3.31
Poplar-Poplar	6.49	5.21	19.86	3.77	2.69	8.76

this diagnosis (111). Sulfate levels in excess of 500 mg/l were obtained in only a very few instances, i.e., East Poplar-IB (summer period, Table 19), East Poplar-Scobey (winter season, Table 24), and Poplar-Bredette (winter season, Table 52), and the sporadically high values of sulfate at the East Poplar-IB station were probably collected in association with the Fife Lake spills since this body of water is somewhat distinctive for the study region in its high concentrations of this ion (Table 62). Several of the other minor Poplar drainage waters also demonstrated sulfate levels in excess of 500 mg/l. As indicated previously, spills from Fife Lake into Girard Creek (Figure 1) have been relatively rare in the past, and these limnetic waters and the surrounding area in Canada can be generally excluded from the effective drainage of the East Poplar sub-basin (55). As a result, the chemical analyses that have been tabulated for this report were obtained through a somewhat unique period, and the maximum summer sulfate levels of the East Poplar would be expected to be generally lower when collected during a more normal and non-spill year.

With respect to Scofield's (1935) sulfate-irrigation classification system listed earlier, the concentrations of this common ion in the various reaches of the Poplar Basin were also generally suggestive of a "good" quality of water for this application with the mean and median sulfate levels at most of the sampling sites typically below 336 mg/l. However, a few samples have been collected from several of the drainage streams with sulfate levels above 336 mg/l, as has been intimated previously, and the mean and median sulfate concentrations at some of the sampling stations did provide obvious exceptions with the statistical concentrations in these cases also in excess of this reference number. These stations would include the East Poplar-IB site during the summer high flow periods, the East Poplar-Scobey location during the low flows of the summer season, and several of the minor drainage waters such as Fife Lake, the West Branch of the East Poplar River, and Calrick Creek near Coronach. But even these reaches, with the possible exception of some of the small accessory streams, would still be "permissible" for irrigation since the sulfate concentrations of almost all of the samples obtained from the drainage, excluding only a few of the minor stream collections, were well within the <336 to 576 mg SO_4/l range during the appropriate seasons. Nevertheless, these assessments do point out that excessive increases in the sulfate levels of the Poplar streams, particularly the lower East Poplar, would be an unfavorable development relative to the value of these waters for irrigation use, and this conclusion is generally supported by analyses based on Doneen's soil-related, potential salinity classification system (Table 11).

In terms of Scofield's class criteria, the below listed factors or seasonal increases in mean-median sulfate concentrations for the various streams would be required to place them into a "doubtful" category for irrigation (expressed as the reference criterion/low flow stream concentration ratios). For the spring season, these ratios can be summarized as follows: >4.0--the East Poplar River and Girard Creek near Coronach and the West Fork Poplar River; 3.0 to 4.0--the East Poplar at the IB, the Middle Fork near Scobey, and the Poplar mainstem near Poplar; 2.5 to 3.0--the East Poplar near Scobey, the Middle Fork at the IB, and the Poplar mainstem near Bredette; and 2.0 to 2.4--the unnamed Creek near Coronach feeding the town reservoir. For the summer period, these factors can be listed more specifically as follows: >4.0--the West Fork near FBB, 3.4--the West Fork at the IB, 2.7 to 3.0--the

East Poplar River and Girard Creek near Coronach, 2.3 to 2.5--the East and Middle Forks at the IB, 2.0 to 2.2--the Middle Fork near Scobey and the Poplar mainstem near Poplar, 1.8 to 1.9--the Poplar mainstem near Bredette, and 1.5 to 1.6--the East Poplar near Scobey and the unnamed creek near Coronach. The determination if such increases in sulfate are feasible for the Poplar drainage with reference to potential impacts derived from the Coronach development will depend upon the results of various water quality modeling efforts now being completed for the region.

In relation to the potential salinity evaluations summarized in Table 68, all of the Poplar Basin streams, by having mean and median potential salinity less than seven milliequivalents per liter (me/l), would have a Class I-type of quality for the irrigation of the well-drained, C-category soils (Table 11), i.e., the Glendive and Banks soils of the Poplar region (Table 1). This Class I designation for the C-type of soil would apply during both the spring and summer irrigation seasons. This is indicative of an "excellent to good" water that is "suitable for most plants under most conditions." The only exceptions would be a few high potential salinity samples (e.g., the maximum values) obtained from the Poplar-Poplar station which were suggestive of Class II or Class III waters.

In addition, the March-May waters in the entire Poplar drainage would also have this Class I designation for use in the irrigation of the A and B category of soils. A few Class II or Class III, high potential salinity samples were again collected from some of the streams, and during the high flows of spring, the mean and median potential salinities of the Poplar-Poplar site (Table 68) were most suggestive of either a Class II (B-type of soils) or a Class III (A-type of soils) water because of the high chloride concentrations of this particular stream segment. But since such high flow occurrences were relatively short-lived with the obtainment of high potential salinity samples generally quite rare, the streams of the basin during the spring season were probably suitable for most of the irrigation practices currently employed in the region. However, with the spring to summer increases in the sulfate and chloride concentrations of the drainage streams coupled with the downstream increases in chloride below Scobey, several possible irrigation problems came to light when such potential salinity evaluations were directed to the summer irrigations of the A- and B-type of soils in the study area, i.e., the Lohler and Haverlon soils respectively.

For the moderately permeable Haverlon soil which is the most commonly irrigated series in the Poplar Basin, all of the major area waters, with one distinct exception and with an occasionally high potential salinity sample, had the mean and median concentrations of this calculated variable during the summer season (Table 68) equivalent to a Class I-type of water for irrigation with potential salinities less than five me/l. As a result, most of the drainage streams would also be suitable for the warm weather irrigation of the Haverlon-dominated regions as well as the Glendive-Banks areas. But because of the comparatively high chloride concentrations of the extreme downstream segment of the river (Table 58), the Poplar River near Poplar represents an obvious exception in having a Class II-type of water for the Haverlon series with its June-October potential salinities typically between five and ten me/l. These down-drainage waters would be "good to injurious" for the irrigation of this soil-type at this time and "harmful to some (plants) under certain conditions of soil, climate, and practices." Thus,

some care should be taken in the summer application of the lower Poplar waters to a Haverlon soil, and any increases in the sulfate and chloride levels of the Poplar River near Poplar much above baseline values would certainly be a detrimental development in relation to this kind of water use. For example, an enhancement of sulfate and/or chloride on the order of 1.5- to 3.8-times in the lower river would make this segment a Class III water during the summer and "unsuitable (for irrigation) under most conditions." For the other streams, sulfate-chloride increases in excess of 2.7- to 5.4-times would be required in order for the Haverlon soil to produce this same condition.

In relation to the above listed increases in potential salinity, if sulfate happened to be the primary concentrating ion, as would be the case for the upper drainage with its low chloride levels, then the upper value of the X-fold factor ranges would be the most realistic criterion for establishing any irrigation degradations of the Haverlon soil. However, if chloride should also happen to increase to a significant degree, as might be the case for the lower Poplar with its high chloride levels, then a lower value in the X-fold factor ranges would be the most likely case. However, significantly larger increases of sulfate and/or chloride over what has been indicated previously would be required to produce Class III Haverlon waters in the spring season or Class III waters for the Glendive-Banks soils.

In terms of the slowly permeable, type A, Lohler soil of the study region, which is the second most commonly irrigated series in the drainage (Table 1), the occurrence of summer irrigation problems would appear to be more likely than the case described for the Haverlon series. In this instance, relatively high potential salinities were obtained in a greater frequency of the basin samples, and the mean and median potential salinity values of several stream stations in addition to the lower Poplar were also suggestive of the worse quality, Class II or Class III waters for irrigation. The classification of the basin streams' potential salinities relative to the Lohler-type of soil for the warm weather period can be summarized as follows: "excellent to good", Class I waters--the East Poplar River and Girard Creek near Coronach (all flows), the East Poplar at the IB (low flows), the Middle Fork at the IB, the Middle Fork near Scobey (high flows), the West Fork (all flows), and the Poplar near FBB (high flows); generally marginal, Class II waters--the unnamed creek near Coronach, the East Poplar River at the IB (high flows), the East Poplar near Scobey (all flows), the Poplar near FBB (low flows), and the Poplar near Poplar (high flows); and "injurious to unsatisfactory", Class III waters--the Poplar River near Poplar (low flows).

Because of their Class II rankings, several of these Poplar drainage streams should be used with caution in any irrigation applications to the Lohler soils during all or parts of the summer season, and the extreme lower Poplar River with its Class III-type of water appears to be generally detrimental for the Lohler irrigations and "unsuitable for most plants (grown in this soil) under most conditions" as a result of the river's high chloride, and consequently, its high potential salinity concentrations. As a consequence, rather small increases in the mean and median sulfate and chloride concentrations of several of the basin streams would certainly be deletrious to this type of irrigation, and the following X-fold statistical enhancements of chloride and/or sulfate, i.e., potential salinity, will be required to

produce Class III waters for the summer low flow irrigations of the type A soils in the study region: the West Fork--2.64 to 6.22, the East Poplar River and Girard Creek near Coronach--2.12 to 4.78, the East and Middle Forks at the IB--1.85 to 3.86, the Middle Fork near Scobey--1.54 to 3.34, the unnamed creek near Coronach and the East Poplar near Scobey plus the Poplar mainstem near Bredette--1.17 to 2.72, and the Poplar mainstem near Poplar--<1.0. The lower numbers of these various X-fold ranges denote a chloride-only increase whereas the higher figure illustrates the case of an increase in sulfate alone.

For the low flow spring period, higher mean and median concentrational increases of these two anions in excess of 1.7-fold and as high as 8.7-fold would be required in most of the drainage streams to produce such Class III Lohler waters. But for the Poplar River near Poplar, these factors would again be relatively low, ranging between 1.57 and 3.64, because of this station's high chloride concentrations. The delineation of the actual occurrence of these ionic increases in the region's waters will be dependent upon the findings of the water quality modeling studies that are now underway as separate investigations.

With three possible exceptions, most of the common constituent concentrations in the Poplar Basin streams should not have any significantly adverse and direct effects on the irrigated plants of the study area. Such constituents would include carbon dioxide-carbonate-bicarbonate (plus total and phenolphthalein alkalinities), calcium and magnesium (plus total hardness), and potassium; SAR and %Na can be considered as inapplicable parameters in this regard. The exceptions reside in sodium and sulfate (and in chloride to some extent), although sodium has also been purported to be required to some concentrational degree for optimum plant growth (117). In addition, since sulfur is a definite macronutrient (110), the fact that sodium and sulfate are readily available in the Poplar streams might be viewed as a beneficial feature for irrigation from a nutritional point of view. However, the high concentrations of sodium in the Poplar drainage waters could be detrimental to this water use by causing leaf burns and defoliations in sodium sensitive species if these waters happened to be applied by sprinkler irrigation (101). But apart from this consideration, sodium concentrations in the basin streams do not appear to be at adequately high levels to have any direct effects on the irrigated plants when these waters are applied by surface irrigations. But it should be pointed out that sodium, sulfate, and the other common constituents such as bicarbonate do contribute to the very high salinity characteristics of the basin streams for irrigation (Table 67), and this particular feature, in turn, definitely detracts from the value of the study region's waters for this agricultural application.

In the case of sulfate and chloride, these two ions on an individual basis would not appear to have any marked effects on the irrigations stemming from the drainage streams. But sulfate and chloride do act in a tandem fashion to provide for adequately high potential salinity levels to be suggestive of some soil-dependent but direct, irrigational degradations in the basin. Such water-use problems would occur most commonly during the summer season and in a down-drainage direction and particularly in relation to those soils that have a relatively poor permeability. Because of this latter feature, considerations of this kind are especially important for the Poplar region since the most commonly irrigated soils of the basin are characterized by having somewhat poor drainage features (Table 1). In gen-

eral, sulfate makes by far the major contribution to the potential salinity levels of the study area streams because of the streams' typically low chloride concentrations. However, chloride also contributes significantly to this derived variable in the lower Poplar River, and it accounts for this segment's distinctively high potential salinity values (Table 68) and for this particular segment's reduced irrigational values.

Common constituents--soil effects.

In addition to the possibility of some directly adverse effects on the plants being irrigated from the Poplar Basin streams, as described previously, certain of the common constituents might also degrade the irrigational quality of the study area waters in an indirect sense by first affecting soil structure. The constituents of most concern in this regard are bicarbonate-carbonate, calcium and magnesium, and sodium. Sodium acts as a negative or degradatory factor when in high concentrations in an irrigation water by causing a dispersed soil condition that is unfavorable for water movement and plant growth (48). In contrast, calcium and magnesium act in a beneficial way to counteract sodium's tendency to retard infiltration and reduce permeability by maintaining the soil's granular structure (48). Potassium can also act in a negative fashion similar to the case of sodium (41), but the low concentrations of potassium in the Poplar streams would be expected to negate any of the problems of this kind that could originate with this particular ion.

The main influence of bicarbonate-carbonate on soil structure is also a detrimental one wherein the presence of these anions in an irrigation application would tend to oppose the positive attributes of calcium for holding good soil tilth and permeability by causing the precipitation of this cation from the soil solution as $CaCO_3$ (41). Such concerns become increasingly more important with the higher concentrations of bicarbonate and carbonate in the streams relative to their calcium plus magnesium levels (32). As noted, sulfate can also cause a calcium precipitation, but the bicarbonate-carbonate ions are more important in this respect than sulfate since $CaSO_4$ is more soluble than $CaCO_3$ with the carbonate precipitations thereby affecting soil structure before the $CaSO_4$ aspect would come into play. As a result, sulfate and potassium will be generally ignored as influential factors relative to altering the structure of the study area soils because of the Poplar irrigations. In addition, the streams' carbon dioxide, total alkalinity, phenolphthalein alkalinity, chloride, and total hardness levels can also be viewed as non-affecting water quality features.

The conflicting sodium versus calcium-magnesium status of an irrigation water is generally expressed in terms of the sodium adsorption ratio (SAR) and the percent sodium (%Na) parameters. The probable effect of a particular bicarbonate concentration for altering soil structure via a calcium precipitation is generally considered in relation to a calculated "residual sodium carbonate" (RSC) factor that has been described previously and is summarized in Table 11. The SAR variable is defined as the concentration of sodium in me/l divided by the square root of 50% of the calcium plus magnesium levels of the same sample, with calcium and magnesium also expressed in me/l (32). The definition for %Na has been presented earlier in this report.

The SAR's obtained from the various Poplar drainage sampling stations varied to a considerable degree and demonstrated over an order of magnitude difference between a minimum value of 0.1 for the basin versus a maximum SAR of 16. The %Na figures also showed a wide difference in magnitude with the minimum and maximum values of this variable equalling 27% and 88% respectively. But within these extreme ranges, the mean and median SAR and %Na data of the basin collections provided somewhat smaller variations with such differences becoming evident both among the several sampling seasons for each of the sampling locations and also among the various basin streams during each of the collection periods. These features are indicative of a quality of irrigation water that changed according to the drainage location and also by the season of the year. Although the SAR's and the %Na's also varied to some extent within each of the station-season data sets, the mean and median values of these compilations are probably quite representative of the type of seasonal quality that might be found for irrigation in each of the basin streams relative to the sodium status of these waters for this agricultural application.

On a seasonal basis, the SAR and %Na values of the drainage samples were moderately high during the non-irrigation winter season, and a distinct decline in these variables typically occurred into the spring season with a further drop developing in association with the high flow stages of the March-May period (e.g., Tables 19, 41, and 52). Such spring declines in SAR and %Na were obtained as a result of the more calcium bicarbonate natures of the Poplar drainage waters during these months as demonstrated by the generally higher HCO_3/SO_4 and the generally lower Na/(Ca + Mg) ratios in the streams at this time of the year (Table 25). But these variables then produced a marked increase into the summer months with the SAR and %Na values of the streams in this June-October season either closely equal to or more commonly higher than those obtained from the winter period. Such spring to summer increases in the SAR and %Na variables were probably related to the distinct decreases in calcium that have been observed in the basin for the warm weather months as illustrated by the declines in the Ca/Mg ratios and the increases in the Na/(Ca + Mg) ratios of Table 25. However in most instances, the relatively high SAR's and %Na's of the summer period did decline to some extent with the onset of higher flows during these months. Excluding the non-irrigation cold weather season, the seasonal changes in the derived sodium parameters of the Poplar streams are additionally illustrated in Table 69, and these data indicate that the Poplar Basin had a better quality of water for irrigation during the spring months on the basis of its sodium characteristics than it had during the summer period.

As indicated in Table 69, SAR and %Na increased in a down-drainage direction in each of the major streams of the basin with a marked increase in these variables through the East Poplar River-Poplar mainstem segments. Of the three forks, the West Fork had distinctively high SAR and %Na values, and the high levels of SAR and %Na in this particular stream would tend to counteract its comparatively good irrigational quality for the basin as has been described previously in relation to its salinity and "potential salinity" characteristics. The inflows of such waters into the mainstem from the West Fork no doubt account to a large degree for the relatively high levels of SAR and %Na that have been observed for the lower Poplar River near Poplar. However, based on calculated sodium concentrations, the accessory waters that enter the Poplar mainstem should also have relatively high SAR

Table 69. Sodium hazard characteristics of the major Poplar Basin streams expressed as their mean, median, and maximum sodium adsorption ratios (SAR) and percent sodium levels (%Na) by irrigation season (IB--international boundary).

	Spring Low Flow			Spring High Flow			Summer Low Flow			Summer High Flow		
	Mean	Median	Maximum	Mean	Median	Maximum	Mean	Median	Maximum	Mean	Median	Maximum
Unnamed Creek-Coronach												
SAR----	3.57	3.51	--	--	--	--	6.01	5.84	--	--	--	--
%Na----	--	--	--	--	--	--	--	--	--	--	--	--
Girard Creek-Coronach												
SAR----	1.75	1.61		--	--	--	5.07	5.06	--	2.64	3.04	--
%Na----	--	--	--	--	--	--	--	--	--	--	--	--
East Poplar-Coronach												
SAR----	2.22	2.17	--	1.41	1.30	--	3.19	3.09	--	--	--	--
%Na----	--	--	--	38.	--	--	46.8	--	--	--	--	--
East Poplar-IB												
SAR----	3.2	2.9	5.6	2.1	1.8	5.0	4.3	4.0	7.7	7.8	7.4	9.6
%Na----	52.5	53.9	59.	50.8	61.	61.5	61.0	61.5	70.9	67.9	68.	71.5
East Poplar-Scobey												
SAR----	4.4	4.4	5.1	--	--	--	7.8	7.1	9.8	7.5	6.7	9.5
%Na----	57.0	56.5	61.	--	--	--	66.9	66.	70.	65.5	65.5	67.
Middle Fork-IB												
SAR----	4.3	4.0	5.3	--	--	--	6.3	5.9	8.1	--	--	--
%Na----	54.0	52.	59.	--	--	--	65.6	66.	73.	--	--	--
Middle Fork-Scobey												
SAR----	4.4	4.7	5.2	3.4	3.4	3.7	7.0	7.0	8.6	3.4	3.4	5.3
%Na----	55.8	57.	59.	47.	--	--	67.4	69.	73.	40.	--	--
West Fork-IB												
SAR----	7.0	7.2	8.0	--	--	--	10.0	10.4	12.	--	--	--
%Na----	54.2	72.	75.	--	--	--	70.8	77.	82.	--	--	--
West Fork-Bredette												
SAR----	7.6	7.8	10.	3.4	3.8	4.5	10.1	11.	14.	5.5	5.5	6.9
%Na----	74.4	76.	82.	64.	--	--	80.9	84.	88.	63.	--	--
Poplar-Bredette												
SAR----	5.9	5.7	6.7	3.3	4.5	5.3	7.2	7.3	8.6	5.7	6.4	6.7
%Na----	66.	--	--	61.	61.	62.	67.8	68.	72.	63.	63.	66.
Poplar-Poplar												
SAR----	7.1	7.0	9.2	8.5	8.5	8.5	10.7	9.7	16.	5.5	6.6	8.3
%Na----	70.0	70.	76.	75.5	75.5	76.	76.5	74.5	83.	67.8	68.	72.

levels with their summer values estimated at 7.2 and 11.4 for the middle and lower reach inputs respectively. These accessory SAR's were determined from the loading calculation data that have been presented earlier in this report for each of the appropriate parameters. As a result of these high SAR's, such accessory inputs should also contribute significantly to the downstream increases of this sodium variable in the main river.

On the basis of SAR and %Na, the quality of water for irrigation from the major Poplar drainage streams and from these accessory inputs can be generally ranked for the low flow irrigation seasons as follows: (1) the East Poplar River drainage above Scobey, (2) the Middle Fork Poplar River, (3) the East Poplar River near Scobey, (4) the Poplar River mainstem near Bredette, (5) the West Fork Poplar River at the IB, (6) the Poplar mainstem near Poplar, (7) the minor middle-Bredette reach inflows, (8) the West Fork near FBB, and (9) the minor lower-Poplar reach inflows. As indicated by this listing and the data in Table 69, the drainage streams most suited for irrigation in relation to their sodium status were located in an up-drainage direction while the worst qualities of water in this regard were found nearer to the basin's mouth. But in general, the SAR and %Na characteristics of most of the various Poplar Basin streams were generally suggestive of a Class II-type of water with reference to the summary in Table 9, at least upon first review, and these Class II waters have been shown to be "good to injurious" for this use, and "harmful under certain conditions of soil, climate, and management practices."

Using the United States Department of Agriculture (USDA) classification system for sodium (57) in relation to the specific conductance and SAR information summarized in Tables 67 and 69 respectively, the sodium hazards of the major Poplar drainage streams for irrigation were established for judgemental purposes. According to the USDA system, the mean and median SC and SAR values of the various drainage sampling stations indicate that none of the Poplar streams should have a high or very high sodium hazard for irrigation. These two classifications would tend to make a water generally unsuitable for this application, and this does not appear to be the case for the streams of the study region. However, it should be pointed out that the maximum SC and SAR levels at a few of the stations and in some of the seasons were certainly suggestive of a potential for high or very high water use hazards of this kind, although these occurrences were found to be quite rare.

More commonly, the upper East Poplar drainage above Scobey afforded a low sodium hazard water for this agricultural use through all of the appropriate seasons whereas the Middle Fork and the East Poplar near Scobey also had this type of water but only during the spring season. In addition, all of the major drainage streams except for the extreme lower Poplar River demonstrated a low sodium hazard condition during the high flow stages of the March-May period. According to McKee and Wolf (1963), these low sodium hazard waters should be suitable for the irrigation of " . . . almost all soils and for almost all crops without detrimental effects . . .," assuming no other limiting factors. These particular streams and seasons, therefore, are undoubtedly suitable for the irrigation of the highly permeable Glendive and Banks soils, and they are also probably appropriate for application to the less permeable Haverlon and Lohler series. But waters with a somewhat lower irrigational quality relative to sodium did become evident in the rest of major Poplar Basin streams.

Apart from the upper East Poplar sub-basin waters and those of the spring season in some of the streams, the remaining courses in the Poplar River Basin most typically demonstrated a medium sodium hazard with reference to the USDA classification system. These streams can be listed as follows: spring season--West Fork Poplar River and the Poplar River mainstem below Scobey; summer season--East Poplar River near Scobey, Middle Fork Poplar River, West Fork Poplar River, and the Poplar River mainstem below Scobey. In contrast to the low sodium hazard conditions elucidated previously, these medium sodium hazard waters point to the necessity of some restrictions on irrigation for optimum yields as implied by the descriptions of a Class II water in Table 9. As a further consideration, the lower Poplar River near Poplar was very close or borderline to providing for high sodium hazard conditions during the summer season because of its particular combination of SAR and SC levels, and this feature would indicate that additional care should be exercised in the irrigational use of this particular stream reach.

Streams with SAR values greater than 10 can cause an appreciable sodium hazard when they are used for the irrigation of soils having a fine texture and a high cation exchange capacity (CEC) (41). With reference to Table 69, this observation would indicate that the West Fork and the lower Poplar River near Poplar should probably not be used for the irrigation of the clayey Lohler soils (and possibly the Haverlon soils) (Table 1) during the June to October period. However, waters with this medium sodium hazard feature are probably suitable for application to the coarse-textured soils with good permeabilities (57) such as the Glendive and Banks series in the study area. Thus most of the Poplar Basin streams probably have an adequate sodium quality at the salinity levels of the waters to allow for a successful irrigation of these latter two soils. For the remaining soils and streams in the drainage, the Environmental Studies Board (1973) indicates that SAR limits between 8 to 18 are generally considered to be within a usable range for general crops, but this question ultimately becomes a site specific deliberation which accounts for the two and one-fourth-fold variation in these prescribed limits. As a result, the SAR range and the maximum SAR limit for any particular irrigable region " . . . depends to some degree on the type of clay mineral, electrolyte concentration in the water, and other variables . . . (24)" that characterize the particular area that is under consideration. Site specific judgements, therefore, have to come into play before a complete evaluation of irrigation can be made for any particular case.

As has been described previously, Klages (1976), after reviewing the water quality and soils information that was available for the Poplar drainage, made several site specific recommendations relative to the irrigation of the Poplar Basin soils in terms of the sodium characteristics of the drainage streams. Using the CEC and the exchangeable sodium data obtained from the Valley County, Montana soils that lie immediately adjacent to the study area (on the order of 8% CEC or 8% exchangeable sodium) (107), Klages (1976) recommends that the Lohler soil, with its high clay content and poor permeability features, should not have irrigation waters with SAR values above 5. In turn, all of the soils in the region at the SC levels of the drainage streams could probably tolerate waters with SAR's less than 5 (36). He further suggests that the coarser-textured soils such as the Glendive and Banks could withstand SAR's in the vicinity of 10, but adds that this

value is probably too high for the Haverlon soil with its finer-textured characteristics (Table 1). Because of the high bicarbonate concentrations of the drainage streams and the potential calcium precipitations that are commonly associated with this anion (13), Klages (1976) suggests an upper SAR limit of 7.5 to 8.0 for the Haverlon soil with this SAR also applicable as a general irrigational reference criteria for the basin as a whole.

Using the site specific reference criteria developed by Klages (1976) in conjunction with the mean and median SAR data summarized in Table 69, the following Poplar streams (and seasons) should definitely not be used for the irrigation of the Lohler soil: the unnamed creek and Girard Creek near Coronach (summer season), the East Poplar River near Scobey and the Middle Fork (summer season), and the West Fork and the Poplar River mainstem below Scobey (spring and summer seasons). Similarly, the following streams (and seasons) should probably not be used for the irrigation of the Haverlon series: the West Fork Poplar River and the Poplar River near Poplar during the summer period, and the West Fork near FBB during both the spring and the summer seasons. Such designations would apply most particularly to the Poplar-Poplar reach during the warm weather months because of this segment's relatively high salinity levels and its borderline, high sodium hazard features at this time of the year. These various restrictions on irrigation from the drainage streams are especially important for agriculture in the Poplar Basin since the Haverlon and Lohler series are the most commonly irrigated soils in the region.

On the positive side, however, several of the Poplar waters are probably suitable for the irrigation of all of the appropriate soils in the study region, although these streams are most typically located in an up-drainage direction. These all-around streams can be listed as follows: the East Poplar River near Coronach and at the IB during both the spring and summer seasons, along with the unnamed creek and Girard Creek near Coronach, the East Poplar River near Scobey, and the Middle Fork Poplar River during the spring season only. In addition and as noted previously, most of the other drainage streams should also be largely suitable for the irrigation of the less-utilized but more highly permeable Glendive and Banks soils with their mean and median SAR's either less than or only slightly above the upper limit of 10, ranging between 6 and 11 in Table 69. But in relation to Klages' (1976) general recommendation for the study region, i.e., SAR's between 7.5 and 8.0, some caution should also be utilized for the Glendive-Banks irrigations in relation to any applications from the West Fork and the Poplar-Poplar reaches because of these segments' high mean and median SAR levels that were commonly in excess of the basin's general criteria. Such added precautions are most pertinent in association with the more slowly permeable Glendive series.

In terms of irrigation use, these various considerations indicate that sodium can be certainly viewed as another critical water quality parameter in the Poplar Basin streams as a result of its potential for adversely affecting the structure of certain of the soils in the region. That is, the high sodium concentrations of the application waters could alter the soils' aggregation and their percolation rates, and this development, in turn, could severely delimit the growth and yield of crops being irrigated in the drainage. In relation to any possible water quality impacts or disturbances impinging upon the basin, as might originate from the Coronach development, Klages (1976) points out that " . . . the SAR of the (irrigation) water should

not be above 7.5 to 8.0. This is about the average currently shown (in the streams) . . ., meaning that little, if any, reduction in quality with respect to sodium can be tolerated if the water is to be used on a permanent basis." Such enhancements of SAR would be most critical for the frequently irrigated Lohler and Haverlon series and least important for the less utilized Glendive and Banks soils.

With reference to the general basin criterion for SAR of 7.5 to 8.0 (36), the below listed increases of this derived variable would obviously degrade the quality of the basin's low flow waters for irrigation. These required X-fold increases in SAR for the various drainage streams by season (Sp--spring and Su--summer) can be summarized as follows: <1.0--West Fork-IB-Su, West Fork-FBB-Su, and Poplar-Poplar-Su; <1.0 to 1.15--East Poplar-Scobey-Su, Middle Fork-Scobey-Su, West Fork-IB-Sp, West Fork-FBB-Sp, Poplar-Bredette-Su, and Poplar-Poplar-Sp; 1.15 to 1.4--unnamed creek-Coronach-Su, Middle Fork-IB-Su, and Poplar-Bredette-Sp; 1.4 to 1.6--Girard Creek-Coronach-Su; 1.6 to 2.0--East Poplar-IB-Su, East Poplar-Scobey-Sp, Middle Fork-IB-Sp, and Middle Fork-Scobey-Sp; 2.0 to 3.0--unnamed creek-Coronach-Sp, East Poplar-Coronach-Su, and East Poplar-IB-Sp; 3.0 to 4.0--East Poplar-Coronach-Sp; and 4.0 to 5.0--Girard Creek-Coronach-Sp.

The above listing also indicates that the qualities of the Poplar region waters for irrigation with respect to sodium are generally better in an up-drainage direction and during the spring season. In many of the streams, such as the East Poplar near Scobey, only minor increases in SAR, e.g., 1.05-fold, would be required to generally degrade these waters for irrigational use, and in some of the streams, as in the Poplar mainstem, no increases in sodium and SAR should occur if these streams are to be maintained at a suitable quality for this water application through the coming years. In general, the basin streams will be able to tolerate much larger SAR enhancements during the March-May, spring period without significantly altering the quality of their waters for irrigation than they would for the warm weather months of June-October.

Streams having a sodium bicarbonate-type of water with high DS and SC levels, like those of the Poplar Basin, inherently provide a relatively poor quality of water for irrigation, especially in application to the slowly permeable soils, because of their typically high salinity (and "potential salinity"), SAR, and %Na characteristics. Such adverse irrigational features have been shown to be the case for many of the streams in the study area, and this aspect was most notable in a down-drainage direction towards the mouth of the Poplar system. As an added consideration, these sodium bicarbonate streams have an additionally poor quality of irrigation water because of their high bicarbonate concentrations which generally produce high "residual sodium carbonate" (RSC) levels. As described by the RSC variable, such high bicarbonate-carbonate concentrations could eventually lead to the development of extra high SAR levels in the soil solution, on the order of 0.5 SAR units for the Poplar system (13, 36), as a result of the calcium carbonate precipitations that can occur in this water phase. This occurrence, in turn, could cause a further degradation of soil structure beyond that related to the sodium content of the application water per se. This latter problem also appears to be an obvious characteristic of the various Poplar streams as illustrated by their mean and median RSC values summarized in Table 70.

Table 70. Residual sodium carbonate characteristics of the major Poplar Basin streams calculated from the mean and median concentrations of the appropriate parameters at each sampling station for each irrigation season (IB--international boundary). Residual sodium carbonate (RSC) has been defined as follows: RSC = $(CO_3 + HCO_3) - (Ca + Mg)$ with the concentrations of the ions in milliequivalents per liter.

	Spring Low Flow		Spring High Flow	
	Mean	Median	Mean	Median
Unnamed Creek-Coronach	1.99*	2.02*	--	--
Girard Creek-Coronach	0.43*	0.70*	--	--
East Poplar-Coronach	1.93	1.94	2.22	2.28
East Poplar-IB	3.01	3.35	1.57	1.29
East Poplar-Scobey	2.67	3.03	--	--
Middle Fork-IB	3.13	2.65	--	--
Middle Fork-Scobey	3.50	3.15	2.47	2.47
West Fork-IB	3.50	4.96	--	--
West Fork-Bredette	6.28	6.79	1.94	1.14
Poplar-Bredette	4.18	4.29	1.52	2.11
Poplar-Poplar	4.63	4.69	4.29	4.29
(extreme high flows)			2.77	2.77

	Summer Low Flow		Summer High Flow	
	Mean	Median	Mean	Median
Unnamed Creek-Coronach	3.45*	3.43*	--	--
Girard Creek-Coronach	3.24*	3.29*	0.77*	1.14*
East Poplar-Coronach	2.89	2.41	--	--
East Poplar-IB	5.19	4.32	6.44	7.27
East Poplar-Scobey	6.10	5.62	5.35	4.75
Middle Fork-IB	4.67	4.40	--	--
Middle Fork-Scobey	5.82	5.97	3.02	3.02
West Fork-IB	7.29	6.29	--	--
West Fork-Bredette	7.98	8.02	4.52	4.52
Poplar-Bredette	4.85	5.27	3.82	4.68
Poplar-Poplar	5.67	5.63	4.17	4.03

*--Denotes an estimated RSC value that might be slightly less than the actual figure because a CO_3 concentration was unavailable and not included in the computation.

The data in Table 70 in comparison to the summary in Table 11 indicate that the RSC levels of almost all of the drainage waters through most of the irrigation seasons were markedly high and typically well above the 2.5 me/l value of this derived variable that has been shown to be detrimental to most irrigation applications (2, 20, 41). On the basis of their high bicarbonate concentrations and their high RSC levels, the streams of the Poplar Basin can be judged as having a Class III-type of water that has a distinctively poor quality for this agricultural use. As indicated in Table 11, streams with RSC values over 2.5 me/l, like those in the study region, have an "unsuitable water for irrigation", and at the very best, the successful use of these streams would certainly require careful management practices.

Because of the sodium bicarbonate character of the basin streams and their generally marginal qualities for irrigation, any water quality disturbances in the drainage that would enhance the content of these two ions over the levels of calcium and magnesium would obviously be an unfavorable occurrence relative to the value of these streams for irrigational purposes. In general, a concentrating effect on the dissolved materials of these waters could perpetrate this sodium bicarbonate over calcium-magnesium development. That is, if bicarbonate-carbonate, sodium, calcium and magnesium happened to be concentrated so that each of these constituents showed a similar increase in levels, such as a doubling over the normal concentrations, then the subsequent RSC values would also show an increase of this same magnitude, i.e., by a factor of two for this particular example. For this same doubling of ionic concentrations, the SAR values of the streams would be increased by a factor 1.4-times. Thus, in the case of the East Poplar River at the IB which currently has an adequate sodium quality for the summer irrigation of the Lohler soils (an average SAR of 4.3, Table 69), if its warm weather DS levels happened to be doubled as might be the case in association with activities stemming from the Coronach development, then its mean June-October SAR level could be increased to a value of about 6.0 which would then make this stream unsuitable for application to the relatively unpermeable, Class A-type of soils in the basin. In view of the presently high RSC levels of the East Poplar (Table 70), as has been described previously, a doubling of this particular variable would also be a disadvantageous development relative to the use of this water for irrigation. These features indicate that the power generation facility in southern Saskatchewan has some obvious water quality impact implications of a detrimental nature in relation to the agricultural use of water from the Poplar drainage streams in Montana, and such implications are particularly distinct for the lower segments of the East Poplar River below Coronach because of this stream's close proximity to the generation site.

Boron.

Boron provides a classical example of the two-pronged nature of many of the water quality variables. That is, this constituent is required by plants in small concentrations for optimum plant growth while being limiting to these plants in a similar sense when found at too low of a concentration, but boron can also be toxic and detrimental and again limiting to these same plants when found in too high of a concentration (110). Boron has been shown to be an essential micronutrient, and the optimum yields for many plants are obtained when boron concentrations on the order of a few tenths mg/l are available in the nutrient solution (24). Conversely, many crops are adver-

sely affected by this constituent when concentrations in the application water achieve between one and four mg/l, and streams with boron levels in excess of four mg/l are generally considered to be unsuitable for irrigational use (24). In addition, most agricultural " . . . authorities agree that for irrigation water the critical concentration is 0.4 to 0.5 mg/l . . . . " due to the fact that " . . . when boron in the irrigation water is 0.5 mg/l, its concentration in the soil solution may be more than 4 mg/l (41)." However, " . . . because plants vary in their sensitivity to boron, waters (have to be) . . . classified not only according to their boron content, but also according to the tolerance of the crops to which they are applied (41)." Such a plant-dependent classification system is presented in Table 12, and this table also lists the general boron tolerances of various commercial plant species.

In the case of most Montana streams, which have an average boron concentration of only 0.1 mg/l (12), the limiting aspects of this constituent as a micronutrient when in too low of a concentration would seem to be the most likely case for irrigation rather than any toxic effects. But the Poplar Basin is somewhat unique for this State in its comparatively high levels of boron, typically between 0.4 mg/l and 2.1 mg/l (e.g., Tables 20 and 49), and the toxic aspects of this element would appear to be the more likely occurrence in this particular instance in contrast to most of the other State streams; the high concentrations of boron in the Poplar streams would be expected to largely negate any nutrient deficiencies of this kind. Table 71 summarizes the mean, median, and maximum concentrations of dissolved boron at the various sampling stations in the study region as obtained from the appropriate "nutrients and other constituents" data tables presented earlier in this report. For the most part, total recoverable boron concentrations, as summarized on a yearly basis in the several "metals and miscellaneous constituents" tables, were not distinctively different at each of the stations from their dissolved levels listed in Table 71. This would indicate that a large proportion of the boron assessed in the many stream samples was present in the dissolved over the sequestered phase.

The dissolved boron concentrations of the Poplar drainage ranged from a minimum value of less than 0.1 mg/l to a maximum of 3.7 mg/l with the total boron levels found as high as 4.1 mg/l in the extreme upper segments of the East Poplar sub-basin. A large part of the boron in the streams is probably derived from such headwaters areas in the basin, although smaller inputs of this kind also apparently originate within Montana since the accessory inflows of water to the Poplar mainstem below Scobey were calculated to have boron levels on the order of 0.7 to 1.0 mg/l. For the basin surface waters as a whole, a typical or median value for this constituent would also stand at about 1.0 mg/l which is an order of magnitude higher than the average concentration that has been established for most of Montana's streams.

As indicated in Table 71, boron concentrations were found to be relatively high in the East Poplar sub-basin which resulted in a somewhat poor quality of water for irrigation in these particular streams. However, a general downstream decline in boron did become evident along the East Poplar-Poplar River mainstem segments with a better quality for irrigation relative to boron therefore evident in the down-drainage reaches in opposition to the observations that have been made for the salinity and sodium parameters. Boron levels were also lower in the Middle and West Forks than in the East

Table 71. Seasonal and flow summary of the mean, median, and maximum dissolved boron concentrations of various streams in the Poplar River Basin.

	Winter Low Flow		
	Mean	Median	Maximum
East Poplar-IB	1.9	1.8	2.5
East Poplar-Scobey	2.0	1.8	3.7
Middle Fork-IB	1.0	1.0	1.2
Middle Fork-Scobey	1.6	1.6	1.8
West Fork-IB	1.3	1.1	2.2
West Fork-Bredette	0.7	0.5	1.9
Poplar-Bredette	1.8	1.7	2.4
Poplar-Poplar	1.0	1.0	1.1

	Spring Low Flow			Spring High Flow		
	Mean	Median	Maximum	Mean	Median	Maximum
East Poplar-IB	1.6	1.8	2.0	0.7	0.9	1.0
East Poplar-Scobey	1.0	1.1	1.2	0.3	0.3	0.5
Middle Fork-IB	0.9	0.8	1.1	--	--	--
Middle Fork-Scobey	0.8	0.8	1.1	0.6	--	--
West Fork-IB	0.6	0.6	0.9	--	--	--
West Fork-Bredette	0.4	0.4	0.5	0.3	--	--
Poplar-Bredette	1.3	--	--	0.8	0.8	0.9
Poplar-Poplar	0.7	0.7	0.9	0.7	0.7	0.8

	Summer Low Flow			Summer High Flow		
	Mean	Median	Maximum	Mean	Median	Maximum
East Poplar-IB	2.1	2.0	3.0	2.0	1.7	3.1
East Poplar-Scobey	2.1	2.0	3.2	1.65	1.65	1.7
Middle Fork-IB	1.5	1.5	1.9	--	--	--
Middle Fork-Scobey	1.5	1.6	1.8	0.4	--	--
West Fork-IB	1.1	1.1	1.4	--	--	--
West Fork-Bredette	0.6	0.6	0.8	0.4	--	--
Poplar-Bredette	1.5	1.5	1.9	1.2	1.2	1.5
Poplar-Poplar	1.2	1.2	1.6	1.0	1.0	1.3

Poplar which is also indicative of a better type of water for irrigation in the more western tributaries. In contrast to salinity and sodium which have a better irrigational status upstream in the drainage, these features are doubly disadvantageous to the East Poplar irrigations since the stream with the highest boron concentrations at the present time and the lowest irrigational value relative to this variable, i.e., the East Poplar River, is the stream that will be the most severely impacted by the Coronach development. The inputs of comparatively low boron waters from the Middle and West Forks no doubt account in part for the downstream decreases in this variable and the improvements in water quality on this basis that have been observed to the Poplar's mouth; however, the unsampled accessory inflows of water to the main river may also have played a role in this regard.

In each of the Poplar drainage streams, boron concentrations were comparatively high during the winter season with a definite decline of this constituent into the spring season which was especially noticeable in associated with the high and extremely high flow stages of the March-May period (Table 71). But boron then increased during the warm weather months to levels closely equalling those of the cold weather period. These summer-winter concentrations of boron possibly point to the type of levels that might be found in the baseline flow component of the streams' discharge. In accord with this observation, boron also dropped to some extent during the higher flows of the summer season in conjunction with the added inputs of water to the drainage courses that were of a non-baseline character. In any event, the basin waters appeared to have a slightly to significantly better quality for irrigation on the basis of boron during the spring season, depending upon the particular streams, than they had during the months of June-October.

Although the boron concentrations of the Poplar Basin waters were at inadequately high levels to affect the stock animals using the streams or the streams' fisheries, some irrigational effects might be anticipated, particularly in relation to the boron sensitive species, since the levels of this element were typically above the lower critical limit of 0.5 mg B/l where some adverse effects might first begin to appear due to a concentrating of the element in the soil solution (41). However, except for the possibility of Fife Lake and upper Girard Creek which is located in close proximity to this lake (Table 64 and Figure 1), boron levels at the various Poplar drainage sampling sites were consistently below 4.0 mg/l which is the critical upper limit for irrigational use, and this suggests that the Poplar streams are not totally unsuited for this agricultural application. In view of the variable tolerances of crop plants to boron concentrations between 0.5 mg/l and 4.0 mg/l, the worth of the basin's waters for irrigation will be dependent upon the types of plants that are to be grown and irrigated in the region. Using the data summarized in Table 71 with reference to the boron classification system in Table 12, the streams in the drainage can be classified and graded as to their applicability towards a watering of the boron sensitive, semi-tolerant, and tolerant crops as summarized in Table 72.

As indicated in Table 72, the Poplar streams are probably not generally suited for the watering of the boron sensitive plants throughout the year. Excluding the winter season, the only exception would be the lower West Fork near FBB, although several of the other streams would be "permissible" to "good" for this application during the spring low flow period and "permis-

Table 72. Summary classification of streams in the Poplar River Basin on the basis of mean and median dissolved boron concentrations for the irrigation of boron sensitive, semi-tolerant, and tolerant plants; this classification was based on the system developed by the Salinity Laboratory of the United States Department of Agriculture (Richards, 1954).

	Spring Low Flow			Spring High Flow		
	Sensitive	Semi-Tolerant	Tolerant	Sensitive	Semi-Tolerant	Tolerant
East Poplar-IB	Unsuitable	Permissible	Good	Permissible	Good	Excellent
East Poplar-Scobey	Doubtful	Good	Good	--	--	--
Middle Fork-IB	Permissible	Good	Excellent	--	--	--
Middle Fork-Scobey	Permissible	Good	Excellent	Good	Excellent	Excellent
West Fork-IB	Good	Excellent	Excellent	--	--	--
West Fork-Bredette	Good	Excellent	Excellent	Excellent	Excellent	Excellent
Poplar Bredette	Unsuitable	Good	Good	Permissible	Good	Excellent
Poplar-Poplar	Permissible	Good	Excellent	Permissible	Good	Excellent

	Summer Low Flow			Summer High Flow		
	Sensitive	Semi-Tolerant	Tolerant	Sensitive	Semi-Tolerant	Tolerant
East Poplar-IB	Unsuitable	Doubtful	Permissible	Unsuitable	Permissible	Good
East Poplar-Scobey	Unsuitable	Doubtful	Permissible	Unsuitable	Permissible	Good
Middle Fork-IB	Unsuitable	Permissible	Good	--	--	--
Middle Fork-Scobey	Unsuitable	Permissible	Good	Good	Excellent	Excellent
West Fork-IB	Doubtful	Good	Good	--	--	--
West Fork-Bredette	Good	Excellent	Excellent	Good	Excellent	Excellent
Poplar-Bredette	Unsuitable	Permissible	Good	Doubtful	Good	Good
Poplar-Poplar	Doubtful	Good	Good	Permissible	Good	Good
Fife Lake-Constance*	Unsuitable	Unsuitable	Unsuitable			
Upper Girard Creek*	Unsuitable	Unsuitable	Permissible			
East Poplar-Coronach*	Doubtful	Good	Good			

* These designations were established from the mean and median total boron concentrations of the sites for the entire year.

sible" to "excellent" for this use during the high flow stages of the spring and summer irrigation seasons. The East Poplar River is the most limiting of the streams in this regard in accord with its comparatively high boron concentrations. Irrigational restrictions of this kind are directed to those crops such as the citrus fruits, nuts, deciduous fruits, American elm, and the navy bean (24, 41), although most of these plants are not generally applicable to the basin's agriculture anyway. But as listed in Table 12, American elm, apple, and blackberries might conceivably be grown in the study region on a noncommercial basis, and these species would certainly be adversely affected to some degree by irrigations originating from the drainage streams during the appropriate season of the year (except for the lower West Fork).

Many of the boron sensitive plants have a tree or shrub morphology, and the absence of phanerophytic riparian vegetation, such as the cottonwoods, along the streams of the upper drainage generally parallels the higher boron levels of these up-drainage waters, and this observation stands in contrast to the presence of this type of vegetation in the lower parts of the drainage which, in turn, coincides with the lower boron concentrations of these down-drainage courses. These features are indicative of a natural cause and effect relationship between boron and the riparian plants that might be attributable to the differing boron concentrations of the various streams in the region, although other factors could certainly play a major role. The major disagreement with such boron-vegetation parallels resides in the absence of phanerophytic plants along the West Fork which also had relatively low boron levels. But in any event, these parallels are definitely suggestive of a need for further study into these matters.

In contrast to the boron sensitive plants, most of the streams of the Poplar drainage had an adequate quality of water relative to boron for the yearlong irrigation of the semi-tolerant plants listed in Table 12. These streams would be placed in either the "permissible", "good", or "excellent" categories depending upon the season and flow, and those waters that were rated as "excellent" in this regard would demonstrate a much lower probability for eventually having adverse boron effects on the crops than the waters that were given a "permissible" ranking. The East Poplar River during the irrigationally important summer low flow season provided a major exception to the boron suitability of the basin's streams for the semi-tolerant irrigations by showing a "doubtful" status for this water use in these months, and Fife Lake and upper Girard Creek would probably be "unsuitable" for this application because of the extremely high boron concentrations of these two systems. As a result, the waters of the East Fork during the summer season (and those of Fife Lake and Girard Creek) afforded a high probability of negatively affecting those plant species that happened to be only semi-tolerant to boron, although this same stream would be "permissible" or "good" for such waterings during the spring months. This observation has some definite implications for the agriculture of the upper drainage by precluding the use of the eastern sub-basin for the summer irrigation of barley and wheat which are the secondarily irrigated plants of the study region (36). However, the other streams can probably be used for these same applications throughout the year as can the East Poplar River during the higher flows of the spring period.

These various aspects also directly correspond to Klages' (1976) site specific recommendation that if barley and wheat " . . . are to be grown,

average boron content should not exceed 2 ppm." As indicated in Table 71, the mean and median boron levels of the East Poplar were either equal to or in excess of the 2.0 mg/l criteria during the summer with maximum values well above this limit, while the remaining streams, i.e., the Middle and West Forks and the Poplar mainstem, and the eastern tributary during the spring season had their maximum boron concentrations and mean and median values below this 2.0 mg/l limit. These considerations ignore the irrigationally unimportant, winter season.

Fortunately, the most commonly irrigated plant in the study area, alfalfa, and the other irrigated species, wheatgrass (36), are fairly tolerant of boron (2, 32). Because of the tolerance of these species, all of the Poplar drainage streams with the exception of Fife Lake and Girard Creek and the East Poplar River during the June to October period, as indicated in Table 72, would be expected to have a "good" to "excellent" quality of water relative to this constituent for the irrigation of these two plants and the boron tolerant species in general. In the case of the East Poplar River, its waters during the summer would be only "permissible" for this use, and this is suggestive of a less desirable but still usable type of water for this application. According to Klages (1976), alfalfa " . . . can tolerate 2 ppm (of boron) readily . . . (while) moderate injury will result from 4 ppm." However, none of the basin's waters, except for Fife Lake, had boron levels in excess of 4 mg/l. Klages further indicates that a concentration of this constituent at 2 mg/l would be best for alfalfa, but that " . . . it could probably yield satisfactorily with 3 ppm (36)." Excluding Fife Lake and Girard Creek, almost all of the water samples obtained from the drainage streams had boron levels well below 3 mg/l (Table 71) with the exception of a few collections taken from the East Poplar River, e.g., the maximum values. These features, therefore, point to a boron quality in the Poplar Basin streams that is probably adequate for the irrigational endeavors that are currently in operation in the region. The major points of caution with respect to these present applications would be directed towards the irrigation of the cereal crops when using waters from the East Poplar sub-basin along with excluding most of the irrigations that might stem from the Fife Lake area in general. Of course this picture could change in the event of any alterations in the agricultural practices of the region, and also in the case that any water quality disturbances should increase the boron concentrations of the various Poplar drainage streams.

In terms of the types of water quality impacts that the basin streams might be able to tolerate relative to boron while still maintaining their present irrigational values, the below listed X-fold increase factors, i.e., a boron reference value divided by a mean or median stream concentration, would make these streams of a "doubtful" caliber for such applications towards the semi-tolerant species. These same increases of boron would also elevate the streams' mean and median concentrations of this element above the levels recommended by Klages (1976) for barley and wheat. These increase factors for the spring low flow season can be listed as follows: the East Poplar at the IB--1.1 to 1.25, the Poplar mainstem near Bredette--1.5, the East Poplar near Scobey--1.8 to 2.0, the Middle Fork--2.2 to 2.5, the West Fork at the IB and the Poplar River near Poplar--2.85 to 3.35, and the West Fork near Bredette--5.0. Much lower increase factors were obtained for the semi-tolerant plants during the low flow summer period of each stream

as follows: the East Poplar River--<1.0 to 1.0, the Middle Fork and the Poplar River near Bredette--1.25 to 1.35, the Poplar mainstem near Poplar--1.65, the West Fork at the IB--1.8, and the West Fork near Bredette--3.35. This feature indicates that the summer season, in terms of irrigation, is much more critical from a water quality impact point of view than the spring period because of the higher boron concentrations that are now present in the streams during the summer over the spring months (Table 71).

Increase factors that would make the basin's waters "unsuitable" for the irrigation of the semi-tolerant crops listed in Table 12 during the low flow periods are presented below:

	Spring	Summer
East Fork-IB	1.4-1.6	1.2-1.3
East Fork-Scobey	2.3-2.5	1.2-1.3
Middle Fork-IB	2.8-3.1	1.7
Middle Fork-Scobey	3.1	1.6-1.7
West Fork-IB	4.2	2.3
West Fork-Bredette	6.0	4.2
Poplar-Bredette	1.9	1.7
Poplar-Poplar	3.6	2.1

In most of the instances, these ratios or factors are greater during the high flows of a season than during the low flow stages.

Similar reference criteria/mean and median stream concentration ratios for boron can also be calculated in relation to the boron tolerant species such as alfalfa. As might be expected, these values were found to be considerably higher than those listed previously for the semi-tolerant forms, and this is indicative of a greater impact leniency in the basin for these more boron tolerant plants. The below listed X-fold increases of mean and median boron would put these streams into a "doubtful" class for the irrigation of the tolerant crops that are summarized in Table 12, and these same increases would lift the streams' boron levels above the site specific value established by Klages (1976) where alfalfa might still provide for satisfactory yields. Such increase factors for the spring low flow season can be summarized as follows: the East Poplar at the IB--1.6 to 1.9, the Poplar mainstem near Bredette--2.3, the East Poplar near Scobey--2.7 to 3.0, the Middle Fork--3.3 to 3.8, the Poplar River near Poplar--4.3, the West Fork at the IB--5.0, and the West Fork near FBB--7.5. Such factors for the low flows of the warm weather, June-October period can be listed as follows: the East Poplar River--1.4 to 1.5, the Middle Fork and the Poplar River near Bredette--1.9 to 2.0, the Poplar mainstem near Poplar--2.5, the West Fork at the IB--2.7, and the West Fork near FBB--5.00.

Increase factors that would make the streams "unsuitable" for the irrigation of the boron tolerant plants during the spring and summer low flow periods are presented below:

	Spring	Summer
East Poplar-IB	2.1-2.3	1.8-1.9
East Poplar-Scobey	3.4-3.8	1.8-1.9
Middle Fork-IB	4.2-4.7	2.5
Middle Fork-Scobey	4.7	2.3-2.5

	Spring	Summer
West Fork-IB	6.3	3.4
West Fork-Bredette	9.4	6.3
Poplar-Bredette	2.9	2.5
Poplar-Poplar	5.4	3.1

The above listed, "unsuitable" X-fold factors would also afford boron concentrations very close to the levels where injury will probably result after the irrigation of alfalfa and wheatgrass with these waters (36). Water quality modeling studies currently underway for the region will establish whether boron increases in the basin streams on the order of 1.8-times to 5.4-times, which would significantly degrade the irrigational worth of the region's waters, might be feasible for these courses in association with the impact characteristics of the Coronach development.

Nutrients, metals, and other constituents.

Apart from boron, the remaining water quality parameters summarized in the several "nutrients and other constituents" tables of this report might be considered as non-affecting or inapplicable factors relative to irrigation. The various nitrogen and phosphorous species listed in these tables would most obviously fall into this category since no critical levels of these constituents have been determined for irrigation by the various referenced authorities (16, 24, 41, 48, 114). In fact, waters with relatively high nitrate concentrations are often viewed as beneficial for this use because of their fertilizing aspects (41). The same rationale might also be applied to waters that are high in phosphorus or phosphate since this element, like nitrogen and potassium, is an important macronutrient that is often limiting to plant growth (110) and thereby applied to the soils via the NPK fertilizers. But in the main, nitrogen and phosphorus would appear to be in much too low of a concentration in the Poplar drainage streams to have either toxic or any significant nutritive effects on the irrigated plants of the region.

For the same reasoning described previously for BOD, COD (and TOC), because of its low concentrations in the basin's waters, can also be graded as a non-affecting factor for the Poplar irrigations in terms of influencing the oxygen status of the soil matrix. In addition, silica " . . . is generally considered to be of little importance in irrigation practice (41)." Although fluoride and iron can be injurious to irrigated plants when in high concentrations in the application waters (41), the typical levels of fluoride in the Poplar streams, i.e., around 0.5 mg/l, were well below the 1.0 mg/l criteria established by the Environmental Studies Board (24) (Table 9) with the maximum basin value just equalling this reference value. In all of the collections, fluoride was far below the 10 mg/l level that McKee and Wolf (1963) claims will not interfere with a water's irrigational value. In the case of iron, its dissolved levels in all of the Poplar drainage samples, and even its total recoverable concentrations except for only a very few of the runoff samples, were obviously beneath the 5.0 mg/l reference criteria for this metal listed in Table 9. As a result, fluoride and iron, like COD, TOC, and silica, also appear to be representative of non-critical water quality variables in relation to this agricultural water use.

As indicated in Table 9, many of the parameters listed in the "metals and miscellaneous constituents" tables of this report, such as several of the metals in addition to iron, can have adverse effects on irrigation. However, most of these variables are best viewed as non-affecting factors in relation to the Poplar Basin. Chlorophyll (Tables 22, 31, 38, 45, and 64) would fall into this latter category as would the phenols (Tables 22, 38, 45, and 64) since this latter constituent " . . . in irrigation water is not considered to be deletrious to crops (41)." The various pesticides that have been assessed for the study region would also appear to be at non-critical concentrations for irrigation since there is little evidence to indicate that the insecticide residues of a water are detrimental to plant growth (24); in addition, herbicide levels have to be far in excess of five ug/l to produce any appreciable damage in the irrigated plants (24). The maximum pesticide level assessed for the Poplar region samples stood well below one ug/l (Tables 22, 45, and 64).

Of the other trace elements that have been assessed for the Poplar drainage collections as summarized in the various "metals and miscellaneous constituents" tables, excluding total recoverable boron, those that can have unfavorable effects on irrigated plants and their associated reference criteria are listed in Table 9. In the case of the other trace elements not included in this table, i.e., Ag, As, Ba, Hg, and Sr, these can be graded as non-affecting factors relative to the Poplar drainage irrigations since no influential concentrations for these constituents have been identified for this water use through various research efforts, or since such affecting concentrations are so high as to be highly unlikely for most natural systems including the Poplar Basin (41). In addition, many of the trace elements listed in Table 9 might also be viewed as unimportant water quality variables relative to the Poplar irrigations because of their low concentrations in the study area streams. Using the concentrational summaries for these elements in Table 66 with reference to their criteria presented in Table 9, nine of these constituents would obviously fall into the non-affecting category with both their maximum total recoverable (TR) and their maximum dissolved concentrations for all of the basin samples falling beneath the corresponding reference values. These elements would include Be, Co, Cr, Cu, Li, Ni, Pb, Se, and Zn. In five cases, i.e., Al, Cd, Fe, Mo, and V, maximum TR levels were in excess of the reference criteria, but since the maximum dissolved levels and the mean and median dissolved and TR concentrations of these elements were well below the appropriate criteria, these constituents can also be placed in the non-influential category relative to the use of the drainage streams for irrigation.

The remaining single trace element, manganese, is probably the most critical of these types of water quality variables for the Poplar drainage irrigations. In this instance, not only did manganese's maximum TR level exceed its reference value, but its maximum dissolved level for the many basin samples was also found to be equal to this critical limit. But as observed for the other trace elements, the "typical" or median (and mean) dissolved (and TR) concentration of this constituent in the drainage waters was placed well below this criterion (Table 66), and as a result of these features, manganese is most suggestive of only a potential problem for irrigation in the event that its concentrations are somehow elevated in the study area streams. For the present time, therefore, this trace element can also be considered as an unimportant water quality parameter for this

agricultural application since almost 100% of the basin samples had dissolved manganese concentrations for beneath its 0.2 mg/l reference level.

On a basin-wide basis, the below listed concentrational increases of the various trace elements will be required before their "typical" drainage values are in violation of their particular reference levels for irrigation. Expressed as the ratio of an element's reference criteria to its "typical" dissolved, drainage concentration (Table 66), these increase factors can be listed as follows: Al--500, Be-->100, Cd-->10, Co-->5, Cr-->100, Cu--200, Fe--125, Li--23, Mo--10, Ni--67, Pb-->1000, Se-->100, V--100, and Zn--200-times. In general, such generally high X-fold increase ratios, in contrast to the relatively low values that have been established for boron, would indicate that the trace elements as a group, except for boron, were not representative of significantly adverse water quality factors for the irrigational uses of the Poplar Basin surface waters, and this stands in contrast to the potentially detractive effects that have been noted for several of the common ions such as sodium, bicarbonate, and sulfate. In turn, a rather significant concentrating of these minor constituents in the basin streams, or a marked increase in their inputs to these waters, would be required before any impact sources such as the Coronach development will be able to make the drainage streams totally unsuitable for this agricultural use on the basis of their high trace element concentrations.

From a different point of view, many of the trace elements such as iron, copper, zinc, manganese, and molybdenum, in addition to boron, act is important micronutrients which are required in low concentrations by plants for optimum growth and development (110). As a result, the presence of low concentrations of these constituents in those streams that are to be utilized as a source of water for irrigation might be, viewed, for this reason, as a beneficial attribute for this agriculture use as well as having a favorable feature as a source of irrigation water because of the non-toxicities that the streams' trace elements would have towards the irrigated plants. This latter aspect now appears to be the most likely case for the Poplar Basin in relation to the levels of trace elements that are found in the drainage streams at the present time. These particular constituents apparently play a relatively minor role in defining the irrigational qualities of the study area waters, and relatively significant water quality impacts will be required to elevate the concentrations of these trace elements to adequately high levels to preclude the agricultural uses of the basin's streams.

OTHER WATER USES AND FEATURES

Drinking Water--the Scobey Municipal Supply

General features and common constituents.

As noted previously, the town of Scobey obtains its municipal water supplies from shallow wells located in the Poplar Basin's alluvium below the confluence of the East and Middle Forks of the Poplar River. A great deal of water quality data is not now available for this supply, and the data that has been collected from this source are summarized in Table 13. However, this water system will be sampled much more frequently in the future

under the auspices of the Safe Drinking Water Act (99), and a more frequent sampling program of this kind is especially critical and highly recommended for this community in view of the potential water quality alterations that might develop in the East Poplar River because of the Coronach power generation facilities that are now being built along this stream. That is, since the aquifers that feed the Scobey town wells are probably recharged by the East and Middle Forks (26, 54), any adverse water quality changes that might occur in the East Poplar River in relation to the drinking water requirements of Table 14 will probably be ultimately felt in the water supply for this town, and this could eventually lead to a lowering of the value of these wells as a source of water for human consumption.

As suggested by Table 13 with reference to the criteria for drinking water that are summarized in Table 14, the water supply utilized by the community of Scobey has, in many respects, a relatively poor quality for this use. However, some of the common constituents that were assessed for this water do not contribute on an individual basis to this poor quality to any significant degree. Chloride provides the most obvious example with concentrations in the well samples far below the 250 mg/l standard listed in Table 14 and with chloride levels also within the "desirable" range for human use as defined by the NTAC (1968). This also appears to be the case for bicarbonate since this constituent is seldom considered to be detrimental to domestic supplies (41). In addition, sodium might also be viewed from this standpoint in spite of its relatively high concentrations in the well collections, as can calcium and magnesium, since no drinking water standards have been established for these three constituents (or for bicarbonate) by federal or state agencies acting from an authoritative and legal base. This would include the Public Health Service Drinking Water Standards established in 1962 (73) and the primary and secondary regulations recently promulgated by the Environmental Protection Agency in association with the Safe Drinking Water Act (113, 115). The State of Montana, in turn, references the Public Health Service recommendations in its Water Quality Standards (44). In addition, neither the Environmental Studies Board (1973) nor the NTAC (1968) made concentrational recommendations for these ions in relation to this water use (Table 14). In essence, these ions are best viewed from an aesthetic rather than a health standpoint (115), and what might be termed as an acceptable concentration for human use is dependent upon the types of levels that the consuming population of a particular area might be willing to tolerate.

Nevertheless, some of these ions do have health implications when in high concentrations, and recommendations that delineate an "ideal" or suitable ionic concentration for drinking water and domestic supply have been established by other entities. Comparisons of the concentrations of bicarbonate, sodium, calcium, and magnesium in the Scobey water system to these recommendations certainly point to the relatively poor quality of the town's wells. It should also be pointed out that these constituents also contribute indirectly to this supply's poor quality by adding to its dissolved solids concentration.

Of the various common constituents, sulfate most obviously degrades the quality of the Scobey supply with concentrations in Table 13 well above the desirable criterion listed by the NTAC (1968); sulfate levels were also slightly in excess of the permissible level, standard, and recommendation

developed by three agencies (24, 48, 73) as presented in Table 14. In addition, sulfate also exceeded the secondary drinking water regulation established by the Environmental Protection Agency (115). However, sulfate concentrations were inadequate in this supply to cause cathartic problems (52, 73) with the main effect of this anion thereby being an aesthetic one by contributing towards an unpleasant taste in the water (115). Similarly, sodium also aesthetically degrades the value of the Scobey wells for human use by providing concentrations well above the threshold levels where various sodium salts such as sodium bicarbonate and sodium chloride can first be tasted in a water (108). In addition, sodium levels in excess of 200 mg/l, as was the case for the Scobey water supply, can also provide some health concerns by being potentially injurious to people that are suffering from cardiac, renal, and circulatory diseases (41).

Similar to sodium, magnesium also has some health implications, but in this case, such influences are related to the inducement of a laxative action in the newcomers to an area, especially when associated with high sulfate concentrations (epsom salts), although most people eventually develop a tolerance to this difficulty upon prolonged exposure to the water (73). In view of this feature, the World Health Organization (WHO) in 1961 recommended a limit for magnesium in drinking water at 30 mg/l for those cases where sulfate exceeds 250 mg/l (100). As indicated in Table 13, waters in the Scobey wells generally violated this WHO recommendation plus the magnesium criteria established by Hibbard (1934) for drinking and cooking which was set at 10 mg/l. But for the most part, magnesium does not appear to be representative of a significant health hazard at the levels found in the Scobey water supply because of the general non-toxicity of this cation to man (41). In contrast to sulfate, aesthetics also do not appear to be a problem in this case with the threshold level for the tasting of this ion in a water observed at 100 mg/l (108) which is well above the magnesium concentrations of the Scobey well samples. In addition, magnesium plus sulfate concentrations in these water supply samples were well below the 1000 mg/l level where most of the people that might be drinking the water would be expected to experience some definite laxative effects (46). Effects of this kind from the Scobey supply would most probably be temporary and relatively mild and directed primarily towards the visitors in the community.

As noted earlier, bicarbonate and calcium are generally viewed as non-critical constituents relative to the value of a water for drinking purposes (41). But the high concentrations of the first constituent were the primary contributors to the Scobey supply's high total dissolved solids levels, and this ion could thereby indirectly degrade the water's quality in this manner. In addition, the markedly high bicarbonate levels of the town wells (Table 13) were also far in excess of Hibbard's (1934) recommendation for a desirable or permissible level of this anion in terms of drinking, cooking, and laundering, i.e., concentrations that are less than 200 mg/l. On these bases, therefore, the high bicarbonate values of the Scobey water system do apparently act to lower the value of these waters for domestic use to some extent.

In the case of calcium, this ion, like bicarbonate, is also generally non-toxic with concentrations as high as 1800 mg/l purported to be harmless to man (41), and calcium as calcium sulfate has been found to be relatively

non-laxative in comparison to the epsom salts (73). As a result, no limiting recommendations for an "ideal" concentration have been put forth by the World Health Organization (100) or by the various other agencies that were listed previously with reference to sodium. As stated by McKee and Wolf (1963), so far " . . . as can be determined at the present time, calcium limits are desirable for domestic supplies not because of a hazard to health, but because calcium may be disadvantageous for other household uses, such as washing, bathing, and laundering, and because it tends to cause incrustations on cooking utensils and water heaters." Hibbard (1934) recommended an upper limit for calcium on the order of 30 mg/l in order to provide for the most efficient domestic use of a water, and the fact that the Scobey wells had calcium concentrations in excess of the value also points to a relatively poor quality of water for this application in the Scobey supply.

In addition, calcium along with magnesium also contribute to the total hardness levels of a water, and high total hardness values are unfavorable for domestic applications for the same reasons noted above for calcium. More specifically, very hard waters are undesirable for domestic uses because of the ineffective action of soap as a result of precipitations, the formation of scums and curds, the gallowing of fabrics, the toughening of vegetables upon cooking, and the formation of scales on pots and pans, pipes, and so on (41). The total hardness levels of the Scobey wells (Table 13) were well above the 80 mg $CaCO_3$/l concentration that is termed as "ideal" by the American Water Works Association (10), and such waters with hardness values progressively above 100 mg $CaCO_3$/l become increasingly more inconvenient and less economic to apply domestically because of the factors cited previously (41). The Scobey supply, like most of the Poplar drainage streams, can be graded as being very hard in nature (10, 19), and this aspect further points to the relatively poor quality of water in the Scobey wells for its use as a municipal supply. But the worth of these waters for this application again depends upon the availability of a suitable alternate source that has a better quality and upon the willingness of the consuming population to tolerate such hard waters in their everyday use.

On the basis of the common constituents, the wells that serve the town of Scobey are apparently adequate as a source of drinking water for this community and as a source of water for other domestic applications, and no major health hazards stemming from the common ions are anticipated as a result of this use. But because of the high concentrations of some of these constituents, this water source may be judged as having a relatively poor quality for domestic supply by producing aesthetic degradations in terms of imparting a taste to the water and also by possibly causing some mild health difficulties such as temporary laxative effects in those persons that are unaccustomed to drinking the water. In addition, the high sodium concentrations of the town wells might pose some problems to those people that are suffering from cardio-vascular and renal diseases. Of additional significance, the hard nature of these waters, which reduces the domestic and economic efficiency of their use, also points to a poor quality for the reasons that have been listed previously.

Dissolved solids and other constituents.

As noted earlier, the common ions can also have an indirect effect in degrading the caliber of a water for domestic applications by contributing

to its total dissolved solids (DS) content, and waters with high dissolved solids concentrations can be rated as having a generally poor quality for this use. As indicated in Table 13, DS levels in the Scobey wells were relatively high, although these concentrations were well below the upper limits in the 4000 mg/l to 5000 mg/l range that would make a water totally unsuitable for drinking purposes because of physiological toxicities (41, 73). On the basis of salinity, therefore, the Scobey wells are apparently usable as a source of water for human consumption in spite of their relatively high DS levels. But the DS concentrations of the Scobey supply were on the order of 4.3-times to 6.2-times greater than the "desirable" level of this variable for domestic applications (48), and they were in the vicinity of 1.7-times and 2.5-times greater than the standard and "permissible" value set forth by the Public Health Service (73) and the NTAC (48); in addition, they were of this same magnitude higher than the secondary drinking water regulation recently adopted by the Environmental Protection Agency as a part of the Safe Drinking Water Act (115). In view of these violations, the Scobey water supply might again be graded as having a relatively poor quality, at least with reference to the excellent types of water that are found in certain of the other Montana water sources such as those obtained from the upper Yellowstone River (86).

In general, violations of the DS criteria for domestic use at the levels that were observed for the Scobey water supply are of concern primarily from an aesthetic rather than a health standpoint with the 500 mg/l reference value listed in Table 14, based on the threshold point for taste instead of any health implications (41); DS concentrations in the Scobey well samples were probably inadequate to produce any cathartic problems in most people (46). At the 500 mg DS/l level, dissolved materials begin to impart a mineral taste to the water, and this becomes progressively more distinct to a greater number of people with DS values exceedingly in excess of this reference criterion (24), as has been observed for the Scobey wells.

"It is generally agreed that the salt concentration of good, palatable water should not exceed 500 mg/l, however, higher concentrations may be consumed without any physiological effects . . . . Each water with a total salt concentration over 1000 mg/l should be judged on the basis of the local situation, alternative supplies, and the reaction of the local population (41)." The Scobey water supply appears to be presently acceptable to the town residents, and they apparently lack any viable alternatives for another source that would not require a considerable expenditure of monies. Because of this latter feature and the high DS and common constituent concentrations of the town supply, any actions that would increase the levels of these water quality variables in the community wells, particularly the concentrations of DS, sulfate, sodium, and total hardness, would certainly be an unfavorable development for the community relative to the value of its water source for domestic use. As noted previously, a rigorous sampling program of these wells should be initiated in the near future in order to identify and monitor the occurrence and severity of any water quality alterations in the upper Poplar drainage that might occur from the nearby Coronach power generation and coal mining operations. Although the frequency of sampling will be intensified for the Scobey supply over that suggested in Table 13 because of the passage of the Safe Drinking Water Act (99), a much more intensive effort is recommended for this particular groundwater source because of its special case characteristics than the frequency that has been specified in

the context of this law (115). These concerns have been transmitted to the water supply engineer of the State Water Quality Bureau who is responsible for the monitoring of these drinking water sources in the eastern segment of Montana (99).

Apart from dissolved solids and the common ions, most of the other chemical constituents summarized in Table 13, except for iron and manganese, were indicative of a relatively good quality of water in the Scobey wells for domestic use. Nitrate concentrations, although somewhat higher in the Scobey supply than the values typically obtained for the basin surface waters, were still well below the reference criteria for this nutrient that are listed in Table 14. These low values of nitrate thereby, at less than 10% of the standard, were unsuggestive of any danger for fatal infant poisonings that have been known to accompany the ingestion of well water (73). Similarly, fluoride, like chloride, was a noncritical factor with its concentrations far below the rejection criteria for this ion based on the "annual average of maximum daily air temperatures" for the region (24, 73). In fact, such low fluoride concentrations in a water supply might be viewed as detrimental for domestic use in one sense by requiring extensive accessory fluoridation, a near doubling in this case, to ensure the maximum protection against dental caries (see Table 14). In addition, arsenic, cadmium, and lead, and even copper which demonstrated relatively high concentrations in the Scobey wells, were at levels far below the reference values for these metals. Although their concentrations were generally above the desirable criteria for these constituents, i.e., a near absence, these trace elements would not be expected to degrade the quality of the town supply to any significant extent. However, iron and manganese present a somewhat different story.

Iron concentrations in the Scobey wells, particularly in the November, 1966 sample (Table 13), were significantly higher than its 0.3 mg/l reference criterion established by several federal entities (24, 48, 73) including the Environmental Protection Agency in its secondary drinking water regulations (115). This was also observed for manganese in relation to its 0.05 mg/l reference value in Table 14. In the case of iron, however, the main concern is primarily of an aesthetic nature since this metal " . . . is not likely to have any toxicologic significance (73)." Iron is an aesthetically unpleasing constituent in domestic supplies at concentrations above 0.3 mg/l because it can impart a brown coloration to laundry, and it can also produce a bitter or astringent taste in a water or in beverages that are made from a high-iron water (115).

In the case of manganese, two reasons are listed by the Public Health Service (1962) for limiting its concentrations in domestic supplies: (1) to prevent aesthetic degradations and the economic losses that might result from quality control, and (2) to avoid any possible physiological damage from excessive intake since some cases of manganese poisoning at extremely high levels have been reported in the literature (41). With reference to the Scobey supply, the second listing does not appear to be an important factor at the manganese concentrations presented in Table 13 since most authorities regard this metal to be of no toxicologic significance (41) except in a few isolated instances. In relation to the first listing, manganese in excess of 0.05 mg/l, as has been observed for the Scobey supply, can impair the taste of beverages such as coffee and tea, and it can also produce

a brownish-black discoloration in laundered goods while causing the occurrence of unpleasant black precipitates from the sloughing of distribution pipes that have been exposed to high-manganese waters (115).

From an aesthetic viewpoint, therefore, the high iron and manganese levels of the Scobey wells should certainly reduce the quality of the town's supply for domestic use to some degree. As a result, some attention should be given to the possibility of treating this water for these metals in order to afford some quality improvements prior to its distribution to the city taps, if such practices are not now in effect. Conversely, any actions that would increase the levels of iron and manganese in the alluvial aquifers of the upper Poplar Basin and thereby in the Scobey water source would obviously be an unfavorable development relative to the quality of the Scobey water supply for domestic applications.

As indicated in Table 13, boron was not assessed in the samples collected from the Scobey wells. But if boron should happen to correspond to most of the other water quality parameters in the table by showing fairly similar concentrations between the wells and the surface waters that recharge the associated aquifer, then boron levels in the Scobey supply would be expected to be relatively high and on the order of 1.7 mg/l. This would not be unexpected since high boron concentrations appear to be characteristic of both the surface waters and the groundwaters of the upper Poplar drainage as illustrated by the high levels of this trace element in the Middle and East Forks and by the relatively high boron concentrations that have been analyzed for several of the wells in the region (Table 13). Boron levels in the Scobey water source, therefore, would be anticipated to be considerably above the desirable concentration for this constituent and also on the order of 1.7-times higher than its permissible level for public supply (Table 14). This is suggestive of some water quality degradations for this application because of the potentially adverse effects that this trace element can have on man, producing a clinical condition known as "borism" when consumed in large concentrations (48).

However, subsequent to the development of the NTAC (1968) recommendation for boron in Table 14, the Environmental Studies Board determined that the available evidence was not indicative of the need for a one mg/l upper limit. They further stated that more information will be " . . . required before deciding whether a specific limit is needed for physiological reasons (24)." On this basis, therefore, the projected 1.7 mg/l concentration of boron in the Scobey water supply, though not desirable, would not seem to be at sufficient levels to cause physiological difficulties since concentrations up to 30 mg/l in drinking water have been shown to be non-deletrious to man (41). Thus, boron does not appear to lower the value of the Scobey well waters for drinking purposes to any marked degree, although some caution should be applied in terms of the general domestic use of this water if such public supplies are to be utilized for plant waterings because of this element's many unfavorable effects for this application. Such adverse effects have been outlined earlier in this report.

Surface Water-Public Supply

General features and field parameters.

None of the municipal water works in the Poplar River Basin obtain their supplies directly from any surface waters in the drainage (75). Thus, considerations of the basin's streams as a source of water for municipal supply might be representative of an inconsequential point relative to the purposes of this inventory. However, some of these water systems, as described for the town of Scobey, plus various private concerns throughout the study area do obtain their waters from shallow community or private wells that are located in the basin's alluvium, and these alluvial aquifers are recharged to a major extent by the surface waters of the region (26, 54). This close interrelationship between the surface resources of the drainage and its shallow wells is supported by the similarity of the water quality data in Table 13 between the Scobey supply and the associated streams, and this stands in contrast to the sharp differences that were obtained between these sets of data and that collected from the other groundwater sources in the drainage. In addition, the Montana Department of Natural Resources and Conservation has tabulated the municipal use of water in the basin (54) as a part of the existing surface water uses in the counties of interest (Table 4). On these bases, therefore, considerations of the Poplar streams as a source of water for public supply might have some validity, particularly for the East and Middle Forks, and all of the major streams of the drainage will be inventoried from this viewpoint for these reasons and also in the case of any eventual changes in the water-use practices of the area.

Most of the various "field" parameters are either inapplicable to considerations of public supply, lacking well established and accepted reference criteria, or they were found to be at inadequate levels in the Poplar streams to be considered as affecting factors in relation to this water use. BOD and dissolved oxygen (DO) are the most obvious examples of the first case, although high levels of BOD and low levels of oxygen-%Sat may be indicative of organic pollution with quality degradations for this application thereby possibly present for other reasons (48). In addition, waters with DO levels below 3.0 mg/l may have a "flat" taste and may develop secondary tastes and odors (59). But since BOD concentrations were relatively low in the drainage streams (e.g., Tables 17 and 55), organic pollution and the associated problems do not appear to be a factor for public supply. Also, DO levels in the Poplar streams were unsuggestive of water quality difficulties with concentrations generally well above the permissible criteria for this water use at 3.0 mg/l and most often fairly close to its desirable or saturated concentration (48). The only exceptions occurred on a few occasions in the upper drainage (e.g., Tables 17, 28, and 44) during the ice cover of the winter season, but these days would represent only a very small percentage of the entire year at these sampling sites.

Flow, when too low, has some obvious restrictions relative to the use of a stream for municipal supply, but considerations of this kind in relation to the Poplar Basin streams are beyond the realm of this particular inventory. In terms of temperature, the NTAC (1968) recommends a maximum value of 85F (29.4C) in order to avoid conditions that might detract from the quality of the raw water that is to be used as source for public supply.

In the case of the study area streams, water temperatures were most typically well below this maximum limit even during the warm weather period (Tables 18, 40, 47, and 57).

For color, the NTAC (1968) recommends a limit of 75 units in order " . . . to permit the defined (treatment) plant to produce water meeting Drinking Water Standards (73) with moderate dosages of coagulant chemicals (48)." The reference criterion for turbidity in surface water supplies that has been put forth by this same agency was based largely upon economic reasons in that the " . . . criterion for too much turbidity in water must relate to the capacity of the water treatment plant to remove turbidity adequately and continuously at reasonable cost (48)." Although such an acceptable maximum turbidity value could vary to some extent in relation to the particular locale, stream, and treatment system under consideration, a general value of 75 JTU was recommended by the NTAC (1968) as an upper limit for this water use; beyond this value, economic and treatment considerations would most likely make the successful municipal use of a high turbidity water highly improbable. Aesthetic factors generally dictate the removal of color and turbidity-suspended sediment from those waters that are to be directed towards domestic applications. However, these variables may also have other unfavorable effects such as scouring, industrial influences, and interferences with other treatment processes.

Although based on a limited number of analyses (Tables 17, 28, 32, 35, 44, and 61), color does not appear to be a critical factor relative to the use of the Poplar drainage streams for surface water-public supply with color fairly consistently below the 75 unit reference value. The color factor would be most important from a treatment standpoint during the high flow periods with a small percentage of the samples having color in excess of its reference value at this time. This same conclusion can also be applied to turbidity with the mean and median levels of this variable typically below 75 JTU (e.g., Tables 17, 39, 46, and 55). The only exceptions in this regard for the Poplar region were also obtained on a few occasions during the high flow stages of the drainage streams which were relatively short-lived with respect to an entire year. In the main, therefore, the various physical attributes of the Poplar streams, i.e., temperature, color, and turbidity-suspended sediment, appear to be at suitable levels so that the streams could serve as a source of water for public supply. Apparently only a minimal level of treatment costs would be required for the removal of the water's turbidity-suspended sediment and color features to acceptable levels.

The waters in the major Poplar drainage courses would also probably be suitable as a source for domestic applications on the basis of its fecal coliform levels since these organisms were consistently below the reference criteria of this variable for surface-public supplies in all of the streams. The median fecal coliform level of the Poplar Basin through all of the seasons stood at only about 35 individuals per 100 ml. But in contrast to the coliforms, pH represents one of the major factors that could detract from the value of the drainage streams as a source for municipal supply. Although pH would not be critical for this use from the "lower end" with pH's in the streams consistently well above the 5.0 and 6.0 minimal reference levels listed in Table 14, this variable could be important with respect to this use from the "upper end" with pH's often in excess of the upper 8.5

limit recommended by the NTAC (1968). This latter feature was most notable during the warm weather months as illustrated in Tables 23, 39, 46, and 55. However, such deletrious aspects of the high pH values for public supply would be less critical in reference to the more lenient pH criteria developed by the Environmental Studies Board (1973) since only a few of the samples from the Poplar streams had pH's in excess of 9.0. The East Poplar River near Coronach would be the most suitable of the basin streams as a source of water for public supply on the basis of pH with its pH levels consistently within the 6.0 to 8.5 range (Table 28); Girard Creek would afford the worst quality for this use with pH typically above 8.5 and often above 9.0 through all seasons of the year (Tables 32 and 61). The other basin streams had pH characteristics that would fall between these two extremes.

Values of pH outside of the 5.0-6.0 to 8.5-9.0 range are less desirable for public supply than the more neutral sources since these low pH or high pH waters can affect treatment processes and can contribute to the corrosion of water works structures, pipes, and household plumbing fixtures (24). Such corrosions, in turn, could lead to the release of toxic metals to the water supply. Depending upon which of the upper reference criteria for pH is utilized in a water quality review, 8.5 or 9.0, the Poplar Basin streams can be rated as having either a fair quality of water for public supply in the first instance, or they might be graded as having a good quality for this application in relation to the latter criteria. This writer opts for the second classification in view of the commonness of pH values in the 8.5 to 9.0 range in many of the natural systems.

As observed in relation to the use of the streams for stock watering purposes, any activities in the basin that might increase the streams' pH levels, such as the Coronach development, would, of course, also degrade their worth for public supply applications. But any such assessments of pH would not be particularly straightforward if the municipal and private domestic waters of the study area continue to be taken primarily from the shallow alluvial aquifers rather than directly from the surface sources because of the subsequent changes in pH that might occur as the water leaves the stream courses to recharge these groundwater systems. This same feature can also be applied to most of the other "field" parameters which are largely non-conservative in nature such as temperature, turbidity-suspended sediment, DO-%Sat, BOD, and the coliforms. As a result, any adverse quality changes in these "field" parameters and pH in the surface water phase might be ameliorated to some degree by the time these waters are eventually withdrawn from the shallow aquifers for public supply. Except for pH, however, impact sources from the Coronach development are not expected to affect these particular variables in the surface water courses to any significant degree. In contrast, dissolved materials and specific conductance are typically considered as being conservative in character, and they are important water quality factors in terms of human use that could be readily affected by the power generation facilities in Saskatchewan. In these cases therefore, a more direct relationship between the surface water impacts and quality changes and any unfavorable DS-SC increases in the shallow groundwater municipal supplies might be visualized for the region. The levels of DS-SC that are currently present in the Poplar Basin streams with respect to their use for surface water-public supply will be considered in more detail in the next section of this report.

Dissolved solids and common constituents.

In terms of public supply, the SAR and %Na data summarized in the various "common constituent" tables of this report might be largely viewed as inapplicable variables relative to this water use except in the sense of utilizing such water sources with high SAR and %Na levels for garden irrigation and plant watering purposes. In this latter case, the previous discussion on irrigation would then apply for these types of accessory applications.

Carbon dioxide is also generally considered to be a non-affecting factor for domestic use since it has no physiological effects as illustrated by the consumption of carbonated beverages, and the only point by concern for public supply is the potential corrosiveness of a high CO_2 (low pH) water (41). However, this would not be expected to be a major factor for the Poplar streams in view of their typically low CO_2 and high pH (>7.0) levels throughout most of the year. In addition, carbonate and phenolphthalein alkalinity are not generally given any special consideration for domestic water use beyond that given to the broader total alkalinity analyses (48). But in any event, carbonate and phenolphthalein levels in the Poplar waters were consistently far below the concentrations of these variables that have been observed to be unhealthful to people (41), and they were typically below the threshold level that can impart a flavor to drinking water, i.e., 44 mg CO_3/l (108). Thus, these two carbon variables per se should not degrade the quality of the Poplar streams for municipal supply, although the high levels of total alkalinity and bicarbonate in the basin's waters could have some adverse effects in this respect.

Some levels of total alkalinity are desirable for a municipal water in order to have sufficient quantities of this variable to react with the hydrolyzable coagulants, such as the iron or aluminum salts, while still providing an adequate residual alkalinity or buffering capacity to maintain a higher pH water that is not excessively corrosive (24). Total alkalinity concentrations above 50 mg $CaCO_3$/l, as observed for the Poplar drainage streams, are desirable for a public supply from this standpoint, although this variable also has a two-faceted feature in the fact that too high of a concentration of alkalinity can provide a drinking water with a distinctly unpleasant taste (24). Such aesthetic difficulties might be assumed for many of the Poplar streams because of their high concentrations of this constituent. The Environmental Studies Board (1973) points out that waters with alkalinities in excess of 400 to 500 mg $CaCO_3$/l are relatively rare, and the NTAC (48) indicates that waters with a total alkalinity greater than this range would be generally unsuitable for public supply use. Except for Girard Creek and the spring high flow season of the basin, most of the drainage streams through most of the other seasons, and the Scobey supply, had mean and median total alkalinity levels in excess of 400 mg $CaCO_3$/l and often in excess of 500 mg/l (e.g., Tables 24, 41, and 52). In addition, the bicarbonate concentrations of these surface waters, like the Scobey source, were also in excess of Hibbard's (1934) recommendation for this variable in terms of an efficient domestic application. As a result, although the high alkalinities including bicarbonate of the basin streams would be beneficial for public supply from one viewpoint, these carbon variables were at adequately high concentrations above the beneficial optimum to lower the value of basin waters as a source for public supply for aesthetic reasons.

Although potassium can be toxic to man when in extremely high concentrations (41), this cation would not be a detrimental factor in the use of the study area streams for public supply because of the low-potassium characteristics of the basin's waters. Chloride would also be noncritical for this use for health and aesthetic reasons with most of the streams, like the Scobey wells, showing concentrations of this anion within the desirable range specified by the NTAC (1968). Even the high chloride, lower Poplar reach (Table 58) had levels of this constituent typically within its permissible range (Table 14) except for a few sporadic summer and winter samples. But unlike chloride and potassium, most of the other common ions assessed for the drainage in addition to bicarbonate-total alkalinity did have adequate concentrations to be suggestive of some water quality degradations relative to the suitability of the streams for surface water-public supply.

As noted for the Scobey wells, sulfate in some of the drainage streams would most obviously degrade their quality for municipal supply with concentrations in these cases slightly above the permissible level listed in Table 14 and slightly above the secondary drinking water regulation established by the Environmental Protection Agency (115). In these streams, e.g., the Middle Fork near Scobey and the Poplar River near Poplar (Tables 41 and 58), mean and median sulfate concentrations most typically exceeded these criteria only on the order of 1.1- to 1.2-times, although more serious violations with factors between 1.2- and 1.7-times were obtained from the East Poplar River near Scobey (Table 24) and the Poplar River mainstem near Bredette (Table 52). These sulfate violations were obtained primarily during the winter and summer seasons with sulfate levels generally higher during the November-February period. In addition, most of the minor streams in the basin also had sulfate levels in excess of this variable's reference value for public supply (Table 62). Such moderately high sulfate concentrations in the major basin streams would probably be inadequate to cause any severe laxative problems in most people, except possibly for some temporary effects in visitors or newcomers to the region, and the primary problems that might stem from this ion would most likely be aesthetic in nature (73).

However, several significant exceptions in terms of any sulfate problems did become evident for the basin waters since the mean and median sulfate levels of these particular streams were found to be less than the 250 mg/l permissible criterion. In these cases, sulfate might be viewed as a noncritical factor for public supply at the present time. These exceptions would include the upper East Poplar River and Girard Creek above Scobey (Tables 19, 29, and 33), the Middle Fork at the IB (Table 36), the entire West Fork, except for the IB site during the winter season (Tables 44 and 48), and most of the other drainage streams during the higher flows of the March-May period. In these instances, the following X-fold increases in sulfate would be required before their waters are degraded on this basis for domestic use: the East Poplar River and Girard Creek near Coronach--1.15 to 1.4 (winter and summer) and 1.8 to 2.3 (spring); the East Poplar at the IB, the East Poplar near Scobey, and the Middle Fork at the IB--1.2 to 1.35 (spring); the Middle Fork at the IB--1.4 to 1.5 (winter and summer); the West Fork--1.4 to 1.8 (winter and summer at all sites) and 2.3 to 2.55 (spring at all sites); the Middle Fork near Scobey and the Poplar River near Poplar--1.45 to 1.6 (spring); and the Poplar mainstem near Bredette--1.1 (spring).

With reference to sulfate, therefore, the above listing indicates that the best quality of water for public supply in the basin streams was found in the West Fork while the worst quality for this use was located in the lower East Poplar and carried through to the Poplar River near Bredette. The West Fork apparently dilutes the sulfate levels of the mainstem to a significant extent in going from the upstream, Bredette site to the river's mouth, and this affords a better quality in the lower reach. A better sulfate quality for domestic applications was also found in the March-May period over the summer and winter seasons in all of the streams. However, some levels of sulfate degradation for public supply might be expected for the entire basin throughout the year since all of the streams in all of the seasons, except for a very few instances during their high flow stages, violated the desirable concentration of sulfate for this use at less than 50 mg/l (48).

As described previously, high calcium concentrations in public supplies are not generally considered to be important in a drinking water from a health standpoint, but this constituent is important for domestic use because it lowers the value of a water for various other household applications such as laundering, bathing, and washing (41). Hibbard (1934) recommended a level of 30 mg Ca/l to define a good quality of water for household use. Similar to the Scobey wells which had calcium concentrations slightly in excess of Hibbard's criterion, calcium also appears to represent a problem for this water use in most of the basin's surface waters. The main exceptions would include Girard Creek (except for the spring season), the West Fork of the Poplar River and the Poplar River near Poplar during the spring and summer seasons, and the Poplar River near Bredette during the summer period which had the mean and median calcium levels of these streams at these times at less than 30 mg/l. Such summer exceptions were related to the sharp decreases in calcium levels that have been observed in the streams for this season possibly as a result, in part, of a biogenetic precipitation of calcium as $CaCO_3$ in association with the high pH's of this biologically active, warm weather period. However, the East Poplar River and the Middle Fork in all seasons, and the West Fork and the Poplar mainstem during the winter, did demonstrate mean and median calcium concentrations that were typically between 1.3- and 1.9-times higher than this reference value.

In addition, calcium may be viewed as a critical water quality variable for public supply because it, along with magnesium, contributes to the total hardness levels of the streams, and the "very hard" natures of most of the Poplar waters (10, 19), as described previously in the "instream specific" inventory sections of this report, are suggestive of a relatively poor quality of water for domestic use. That is, the total hardness levels of all of the streams were well above this constituent's "ideal" concentration for a household water (10), and the levels of this constituent were also typically between two- and four-times higher than the 100 mg $CaCO_3$/l concentration where domestic applications might first become somewhat inefficient because of the presence of this water quality factor (41). The degradatory aspects of high total hardness levels in a water have been described previously in conjunction with the Scobey water supply. As a result, such high calcium and total hardness concentrations would definitely lower the worth of the basin streams for public supply in the case that they should eventually be used for this purpose.

Magnesium can also be viewed as an important water quality parameter for public supply by also contributing to the very high total hardness levels of the study area streams, and this appears to be the main degradatory feature of this particular cation in relation to this water use. Although magnesium can afford some taste and health problems when in adequately high concentrations (41), aesthetic degradations should not be a factor for the Poplar streams with their mean and median magnesium concentrations well below the 100 mg/l level where this constituent might first be tasted in a drinking water (108); magnesium exceeded this 100 mg/l level in only a very few of the samples collected from the streams. In addition magnesium would not be suggestive of any pronounced health difficulties upon consuming the basin's waters since the magnesium plus sulfate concentrations of the streams (epsom salt) were for beneath the 1000 mg/l level that would produce laxative effects in most of the people drinking from these sources (46, 73). However, some mild actions of this type, particularly in the newcomers to the region, might be anticipated for certain of the streams if they happened to be used as a source of water for municipal supply since the magnesium and sulfate ions in tandem did exceed the WHO recommendation for these constituents in drinking water (100), i.e., magnesium > 30 mg/l with sulfate > 250 mg/l.

Streams that would fall into the high magnesium-high sulfate category include the East and Middle Forks during the winter and summer periods, the West Fork at the IB during the months of November-December, the Poplar mainstem also during the winter and summer seasons, and most of the minor streams in the drainage such as Calrick Creek. Exceptions in this regard because of the low concentrations of sulfate but with magnesium greater than 30 mg/l would include the upper East Poplar River and Girard Creek above Scobey plus the Middle Fork at the IB during all of the seasons, and the East and Middle Forks near Scobey plus the Poplar River near Bredette during the March-May span only; exceptions in this regard with magnesium levels less than the WHO criteria would include the West Fork at the IB during the spring and summer periods, the West Fork near Bredette in all of the seasons, the Poplar River near Poplar during the spring months only, and most of the basin waters during the high flow stages of the spring season. However, some degree of magnesium degradation for public supply would be expected for all of the basin's waters including the exceptions listed above since most of the streams did have magnesium levels in excess of Hibbard's (1934) recommendation for this cation in terms of an optimum efficiency for drinking and cooking purposes (104). As noted for sulfate, the West Fork of the Poplar River probably has the best quality of water of the basin streams for municipal applications on the basis of its relatively low calcium, magnesium, and total hardness levels in addition to its comparatively low sulfate values.

Like bicarbonate and sulfate, sodium concentrations in the Poplar drainage streams were also relatively high, and these three constituents, thereby, would also degrade the value of the basin's waters as a source for public supply by contributing to the streams' high dissolved solids levels. These three variables accounted for nearly 85% of the mean DS content of the Poplar River near Poplar. In addition, sodium, at the concentrations detected in many of the streams, i.e., typically in the 200 mg/l to 350 mg/l range, should also have some degradatory attributes for municipal use on its own right with the concentrations of several of the sodium salts, as noted

for the Scobey wells, at adequate levels to impart a taste to the water (108). In addition, many of the drainage streams had sodium concentrations in excess of the 200 mg/l value which can pose some health difficulties for those people who might eventually drink the water when suffering from renal or cardio-vascular diseases (41). Using the 200 mg Na/l value as a guide, streams affording the greatest penchant for degrading a public supply on the basis of their sodium concentration would include the East and Middle Forks near Scobey, the entire West Fork, and the Poplar mainstem below Scobey. But less distinct problems of this kind would be evident in these streams during the spring months because of the runoff dilutions, and quality degradations from sodium for human use would not be expected for the upper segments of the East and Middle Forks above Scobey or for Girard Creek because of the relatively low concentrations of this constituent in these particular reaches through all of the seasons.

In the case of most of the Poplar streams in most of the seasons, any actions in the study region that would increase the levels of sodium in these waters would certainly be an unfavorable occurrence relative to the value of the streams as a source for future public supplies, as well as causing a reduction in their worth for agricultural applications. Such municipal supply degradations would also apply to the concentrational increases of many of the other common constituents, i.e., bicarbonate, sulfate, calcium, and magnesium, and this observation is most pertinent in relation to the total hardness variable in terms of maintaining a status quo with respect to the particular level of domestic use efficiency that is now at hand in the region.

As indicated in Table 67, DS concentrations in the various Poplar drainage streams were relatively high, and the median seasonal low flow levels of DS in the region, including the winter season, ranged from 545 mg/l to 1280 mg/l. But like the Scobey wells, such levels were inadequate to make the streams completely unpotable for physiological reasons (41, 73). In addition, these "typical" DS concentrations were below the 2000 mg/l standard that could cause some definite laxative actions in most of the people consuming the water (46), although a few of the samples that were obtained from the drainage did have DS concentrations greater than this value (Table 67). In the case of the Poplar streams, any health effects of this kind would most likely occur in those visitors to the area that happened to be unaccustomed to drinking the water, and even these difficulties would be expected to be relatively mild and temporary since most people generally become quickly acclimated to the use of such moderately high DS sources (73). But regardless of these features, some quality degradations for domestic use are still inherent to the basin streams because of their high DS contents with the "typical" or median yearly DS level for the entire basin, calculated at 860 mg/l, about 4.3-times higher than the "desirable" concentration of this variable for this application (Table 14) (48) and about 1.7-times greater than the permissible criteria of the NTAC (1968); this variable was also of this same magnitude higher than the public supply recommendation established by the Environmental Studies Board (1973) and the secondary drinking water regulation adopted by the Environmental Protection Agency (1977) and the Public Health Service (1962).

In general, the best quality of water for municipal use in the drainage on the basis of dissolved solids would be obtained from the streams during the spring season, particularly in conjunction with the higher flows of this

period (Table 67), although the higher turbidity-suspended sediment and color features of the streams at this time would tend to lower this better quality to some extent. In addition, a somewhat better DS quality for public supply would also be generally obtained in the summer over the winter months and also in an up-drainage direction through the region.

As intimated in the above discussions, the major Poplar Basin streams appear to be usable as a source of water for public supply, although they were not of a desirable quality for this use because of their high DS levels. Except for the possibility of a mild laxative action in newcomers to the Poplar region, the primary DS degradation of the drainage streams for municipal use would be aesthetic in character with these waters' DS levels commonly above the 500 mg DS/l threshold level for taste (24, 41). On these bases, therefore, any increases of DS in the streams much over their present levels because of this taste factor, or much over the 2000 mg/l concentration because of health-laxative reasons, would certainly be undesirable in the case that these waters should be eventually utilized as a municipal source in the coming years. A 2.3-fold increase in the median yearly DS value of the drainage (860 mg/l) could cause the occurrence of more definite and severe laxative problems in most of the consuming population, and a 4.6- to 5.8-fold increase in this statistic would make at least one-half of the streams totally unsuitable for this water use through most of the year because of physiological toxicities. Such increases, in turn, would also enhance the taste characteristics of the water. A preliminary review of potential impacts associated with the Coronach development indicates that two-fold increases in dissolved materials for the East Poplar River subsequent to the initiation of the power plants are not totally unreasonable. However, this concentrating factor and the associated water quality impacts should become progressively smaller in a downstream direction in the Poplar River mainstem below Scobey, and also in the East Poplar towards Scobey, because of the diluting effects of confluent streams and groundwater inputs.

Nutrients and other constituents.

Boron concentrations in the Poplar streams were relatively high with respect to the State's average for this constituent in surface waters (12), and with the exception of the lower West Fork and the spring season in some of the courses, boron was above the desirable and permissible levels of this trace element for public supply (48). But similar to the case that has been noted for the Scobey wells, the Environmental Studies Board (1973) indicates that such high levels of boron would be inadequate to significantly degrade the value of the streams for this water use. Fluoride can also be placed into the same category with boron since its levels in the Poplar streams and in the Scobey wells were also well below this ion's public supply-drinking water criteria in relation to the continental temperature characteristics of the region. As suggested in Table 14, accessory fluoridation would be required in order to bring these supplies' fluoride levels up to an optimum for dental reasons. About a 25-fold increase in the yearly median dissolved boron concentration of all of the drainage surface waters (1.2 mg/l) would be required before some adverse effects on human health after consumption might be anticipated at the 30 mg/l level because of the boron-related digestive interferences that can occur at these very high concentrations (41). In the case of fluoride, a 5.5- to 6.0-fold increase in its yearly median concentration for the basin (0.4 mg/l) would be needed before these surface

waters would constitute a rejection for public supply. In another sense, a 2.8-fold increase of fluoride in the streams might be construed as a beneficial development for domestic use by putting this ion at optimum levels from a dental health standpoint without the need of separate fluoridations.

But in contrast to the Scobey water source, iron in the drainage streams was unsuggestive of any water quality problems for municipal use with the levels of this constituent in the surface waters far below that observed for the shallow alluvial aquifer near Scobey. This discrepancy indicates that some factors other than surface recharge also had some influences on the quality of the water in the Scobey wells. In the case of the streams, almost all of the water samples, regardless of their generally high total recoverable iron concentrations, had the more important dissolved iron variable at concentrations far less than the 0.3 mg/l reference level of this particular metal for surface water supply. As a result, although the dissolved iron concentrations of the streams were often above the desirable value for this constituent (Table 14), taste and staining from excessive iron should pose no major problems relative to the domestic use of surface waters from the Poplar region.

Silica, with levels in the Poplar streams generally not too much different from the State and national concentrational averages of this element (12, 83), is best viewed as a non-affecting factor for human water use since in the " . . . concentrations found in natural . . . waters, silica or silicates appear to have caused no adverse physiological effects . . . (41)." The combined nitrogen species, i.e., TN, TON, and TKjN, and COD (and TOC) at the non-pollutional levels noted for the basin streams might also be considered as non-affecting factors for this water use since no public supply criteria for these constituents have been established by various authorities (24, 41, 44, 48, 73, 113, 114, 115). However, the inorganic nitrogen species, i.e., nitrite, nitrate, and ammonia, can have detrimental effects on public supply when in high concentrations as suggested by Table 14. But as observed for the Scobey wells, nitrite-nitrate should present no difficulties to the domestic use of the Poplar surface waters with NO_xN concentrations in all instances well below the various reference criteria of these constituents for infant consumption. That is, methemoglobinemia due to nitrite-nitrate should not be a factor for young children drinking this water.

Like nitrate, ammonia concentrations of most of the Poplar streams were also relatively low with the levels of this particular nitrogen species well below its 0.5 mg N/l reference value in almost all of the samples collected from these particular drainage waters. This would include the Middle Fork, the West Fork, the East Poplar near Scobey, and the Poplar mainstem below Scobey (e.g., Tables 42, 49, 53, and 59). The major exceptions in this regard consisted of the upper East Poplar sub-basin above Scobey, including the East Poplar River at both its IB and Coronach stations (Tables 20 and 30), Girard Creek and its small tributary feeding the Coronach town reservoir (Tables 34 and 63), and possibly Fife Lake, with a large percentage of the samples obtained from these sites having ammonia levels greater than the 0.5 mg N/l value. As illustrated in Tables 20 and 26, such ammonia problems would appear to be more severe in the winter season and during the high discharge stages of the streams than in the summer months or during the lower flows of the March-May period.

In contrast to NO_XN, the main concern for high ammonia concentrations in municipal water sources is not related to toxicity but rather to the fact that ammonia can interfere with the chlorination process and reduce the disinfection capacity of this treatment at levels above 0.5 mg N/l (24). An effective chlorination would be important for the Poplar Basin streams since the fecal coliform levels of the raw supply waters were generally above the standard and above the primary drinking water regulation adopted for this variable by the Public Health Service (73) and by the Environmental Protection Agency (113). The high ammonia concentrations of the upper East Poplar sub-basin, therefore, could impose disinfection problems of this type on public supply, and any increases of this nitrogen variable in these particular streams would certainly be disadvantageous for this water use. For the other Poplar streams, however, rather significant increases of median ammonia levels on the order of three- to six-times and as high as fifty-times might be tolerated without significantly altering their value for public supply purposes, and all of the basin streams would be able to tolerate marked enhancements of median NO_XN concentrations on the order of 100- to 1000-times without degrading their worth for this potential water application.

Another critical aspect of ammonia relative to the municipal use of a water resides in its action as a eutrophic factor. This feature is important in the Poplar Basin since these streams were generally nitrogen limited in accord with the observation of Gerloff and Skoog (1957) with phosphorus typically over its reference level for stream eutrophy but with NO_XN typically under this criterion for nitrogen. Since NO_XN alone did not generally achieve the eutrophic status for nitrogen in the drainage waters, considerations of the NH_3N factor then become important in this regard since this variable did lift the TSIN (total soluble inorganic nitrogen) levels of some of the drainage streams to values in excess of the lower eutrophic criterion for this critical nutrient. This feature in combination with the high phosphorous concentrations suggests that these particular streams could be potentially eutrophic, and eutrophy is an unfavorable occurrence in public supplies because of filter clogging, coloration, oxygen depletion, water treatment, and taste and odor problems, and also because of the potential for toxic algal residues in such sources (102). However, the occurrence of such public supply difficulties does not appear to be the case for the Poplar drainage streams in general, and most of the basin's waters are best graded as being non-eutrophic, regardless of the adequately high phosphorous concentrations, because of a nitroten limitation due to their low NH_3N, NO_XN, and TSIN levels.

The major exceptions to non-eutrophy in the drainage were found to occur in the upper East Poplar sub-basin with these streams possibly eutrophic for a large part of the year (see Table 21) as a result of their uniquely high ammonia concentrations. The associated difficulties described previously, therefore, could operate as definite degradatory factors in relation to the future use of these upper East Poplar streams for public supply. However, supplemental field work will be required to establish the actuality of eutrophy in these waters because of the borderline nature of their nutrient levels. Of course, any additional increases of TSIN in these particular streams, whether as NO_XN or as NH_3N, could be disadvantageous to this water use by enhancing the probability for eutrophic conditions and its associated difficulties. In contrast, the remaining streams of the basin, e.g., the

West and Middle Forks and the Poplar River mainstem, might be able to withstand fairly large increases of TSIN as NO_xN and/or NH_3N without causing the development of eutrophic problems because of their naturally low inorganic nitrogen concentrations.

Phosphorus as phosphate or polyphosphates is another important water quality variable to consider for public supply from a eutrophic standpoint (24), and this constituent was typically over the 0.05 mg P/l lower reference criterion for eutrophy in many of the Poplar drainage streams. However, such high phosphorous levels should not be viewed as a particularly exceptional condition to the Poplar region per se since 48% of the aquatic sites that were collected from across the nation during a water pollution survey conducted in the 1950's and 1960's produced phosphorous levels in excess of this value (29). Major exceptions to this observation within the study area were found to occur primarily during the winter and/or spring seasons in some of the streams and also towards the lower reaches of the Poplar Basin. In the other instances, total phosphorus was probably at adequate levels to produce eutrophic conditions in these segments given the absence of any nitrogen limitations.

In those streams that were definitely nitrogen limited, as listed earlier, additional increases of phosphorus in the waters would probably not be particularly critical for eutrophy because of the limiting action of the second nutrient. However, since phosphorus can have some other adverse effects on public supply apart from the eutrophication feature, these aspects of phosphate should also be considered in relation to this water use, and excessive increases of this nutrient might also be detrimental to domestic applications because of these accessory factors. But for the streams having both their nitrogen and phosphorous levels over these constituents' reference criteria for eutrophication, such as the waters in the East Poplar sub-basin, any further increases of total phosphorus would be expected to be unfavorable for public supply by also enhancing the probability of stream eutrophy and by potentially enhancing the development of those water-use problems that are commonly associated with this condition, as has been described previously. Thus, any activity that would increase the total phosphorous levels of the East Poplar sub-basin should be avoided if these streams are to be utilized as a source of water for municipal supply. In contrast, these eutrophic type of impacts should be much less important to those parts of the drainage that have nitrogen-limited waters, although any increases of phosphorus in these cases could also degrade the public supply values of the streams but for other reasons.

In addition to the eutrophication factor, phosphorus as phosphates can also have adverse effects on municipal use by affording a laxative action at high concentrations in the 450 mg/l area (109), and Manz (1955) suggested that the 50 mg/l level of polyphosphates (16.3 mg P/l) should not be exceeded in a drinking water because of this reason. Lockhart, et al (1955) found the taste threshold for phosphates to stand at about 180 mg/l (58.7 mg P/l). In addition, phosphates can degrade a public supply by interfering with the coagulation, flocculation, and lime-soda treatments of the raw-water source (24, 41). In the case of taste and laxativeness, the Poplar Basin should afford no problems to domestic use because of the streams' comparatively low total phosphate levels in relation to the 16.3 and 58.7 mg P/l reference values that have been established for these two adverse attributes of the ele-

ment. But interferences with coagulation can occur at 0.1 mg P/l (24), and this feature, therefore, may afford some occasional difficulties to the use of the drainage streams for public supply since total phosphorous concentrations in some of these waters were sporadically in excess of this particular value throughout the year. As a result, relatively small and additional increases of phosphorus in the basin streams, which might be feasible for some of the segments in terms of the Coronach development, such as the lower East Poplar River, could be disadvantageous for public supply purposes because of the water treatment difficulties that might arise from this development, as well as for eutrophication reasons. However, the large increases in phosphorus that would be required to produce taste or laxative problems seems to be highly unlikely for the streams in view of any quality impacts that are potentially facing the study region at the present time.

Metals and miscellaneous constituents.

Table 14 lists the reference criteria that have been established for fourteen of the trace elements, including the phenols, by three federal entities (24, 48, 73). Of these, boron and iron have been considered previously in this review in relation to their possible effects on domestic water use. In the case of eight of these trace constituents, i.e., Ag, As, Ba, Cd, Cr, Hg, Pb, and Se, these criteria were established primarily for toxicity and health reasons, and similar reference values for six of these elements have also been recently adopted by the Environmental Protection Agency to serve as primary drinking water regulations in association with the Safe Drinking Water Act (113). This agency at the same time established standards of 0.05 mg/l and 0.002 mg/l for arsenic and mercury respectively. For the remaining trace elements listed in Table 14, i.e., B, Cu, Fe, Mn, Zn, and phenol, standards were established primarily for aesthetic reasons as described previously for iron and manganese. Similar reference values to those in Table 14 were also adopted for Cu, Fe, Mn, and Zn by the Environmental Protection Agency for their secondary drinking water regulations (115).

As suggested by the trace element data summary in Table 66, most of these constituents in the Poplar Basin streams, although often not at their "desirable" concentrations for domestic use (a near absence), were generally unsuggestive of severe problems for municipal supply since their drainage concentrations were, in most instances, typically below the corresponding reference criteria. Ba, Cr, Se, and Ag would most obviously fit into this category with both the maximum dissolved and the maximum total recoverable levels (TR) of these trace elements falling below their reference values. This was also the case for arsenic in relation to the Environmental Protection Agency's more linient primary regulation (113). However, the dissolved and TR levels of arsenic did exceed the Public Health Service's (1962) more stringent standard (Table 14) on occasion as illustrated by its maximum concentrations in Table 66, although arsenic was never at adequate concentrations to constitute a rejection of the supply relative to the Public Health Service requirement. Similarly, the dissolved and TR concentrations of mercury in a few of the samples collected from the Poplar streams were also in excess of the standards established for this element (24, 113), but it seems highly unlikely than an average level of mercury from any four consecutive stream samples would exceed the 0.002 mg/l value for any of the basin waters and thereby constitute a rejection of this potential source (99). More logically, the low median dissolved and TR values of arsenic and mercury, in ad-

dition to Ba, Cr, Se, and Ag (Table 66), would indicate that the basin's waters should probably be usable for public supply purposes. This was also the case for cadmium and lead in view of their low dissolved concentrations even though their maximum TR levels from the drainage streams did exceed their reference criteria.

The above observations do suggest, however, that arsenic and mercury should be monitored fairly closely in the study area waters in regard to the Coronach power generation facilities, and any increases in these two constituents should be avoided in order to prevent any further degradations of the public supply potential for the region. Of course, concentrational increases in the other trace elements would also make these streams less "desirable" for this application, although relatively large enhancements of their median dissolved levels on the order of 25-fold for As, Ba, Hg, and Pb, and on the order of 50-fold for Ag, Cd, Cr, and Se, would be required to make these streams totally unsuitable for domestic use on this one particular basis.

As described previously, iron concentrations in the Poplar drainage streams were unsuggestive of aesthetic degradations for municipal supply, and this also appears to be the case for copper and zinc with their basin concentrations well below the reference levels that have been established for these constituents (comparing Tables 14 and 66). Concentrational increases in the basin's median dissolved levels of these latter two elements in excess of 100-fold would be required for these two metals to produce continuous aesthetic problems for domestic use. Manganese appears to be somewhat more critical in this regard than copper and zinc since only a five-fold increase in the region's median dissolved level of this particular metal could cause continuous taste and staining difficulties for domestic applications. At the present time, such manganese problems would appear to be much more sporadic than continuous in nature since its dissolved levels were only occasionally in excess of the appropriate reference level with its median dissolved concentration for the drainage standing at about 20% of this value. However, the TR concentrations of manganese, in contrast to its dissolved levels, were quite frequently above this reference criteria as illustrated by its high median TR value for the basin in Table 66, and extremely high TR concentrations were obtained from a few of the drainage samples. Like the case for iron, such high TR features are possibly suggestive of a potential for the development of manganese (and iron) problems in the basin, especially with the advent of major water quality disturbances, but in the main, these metals do not now appear to be significant degradatory factors relative to the use of the drainage streams as a source of water for public supply.

Of the trace elements, the phenols would seem to rate the most consideration at the present time with reference to any potential reductions in the public use values of the Poplar streams; that is, the limited amounts of phenol data that are now available for the study area demonstrated concentrations commonly in excess of its 0.001 mg/l criteria (24, 48, 68, 73) in those waters that had been assessed for this variable (Tables 22, 35, 45, and 64, and Table 66). In general, the phenols at the levels assessed for the basin streams should be much more important from a public use sense than they are in terms of having any major and direct effects on the aquatic biota. The main point of concern for this trace constituent in municipal supplies is

related to the taste and odor problems that can develop from high phenol waters, particularly after their in situ halogenation subsequent to treatment by chlorination since the chloro-substituted phenols are much easier to detect organoleptically than the unsubstituted forms (24). For example, non-halogenated phenols such as m-cresol and o-cresol have a threshold order concentration in the vicinity of 0.25 mg/l whereas the chlorinated phenols, especially the para-substituted form, can be detected in much lower concentrations approaching 0.002 mg/l (24). With a median phenolic value for the drainage standing at 0.005 mg/l (Table 66), these features could pose some definite aesthetic problems relative to the eventual use of these waters for municipal distribution. As noted, the phenols can be derived from natural and unpollutive sources (24, 33), and this appears to be the most likely source of this constituent in the study area streams. But any further enhancements of their levels in these waters from pollutive sources would certainly be in unfavorable development relative to the worth of these streams for public supply.

The remaining trace elements summarized in the "metals and miscellaneous constituents" tables of this report, e.g., Tables 27 and 60, but not discussed above, including Al, Be, Co, Li, Mo, Ni, Sr, and V, might be viewed as non-affecting factors for public supply since no reference criteria have been established for these variables (Table 14). In these cases, either no instances of human toxicity of obvious aesthetic degradations have been reported in the literature (41), or the required concentrations are so high as to be extremely unlikely for most natural systems. In the case of strontium, it " . . . is evident that the major hazard to humans of radiostrontium in water lies not in direct consumption but in plants and fish that accumulate this element (41)." In view of this information, the low concentrations of these eight trace elements, including strontium, in the Poplar Basin streams (Table 66) are certainly indicative of the absence of any water quality problems for public use that might conceivably originate with these constituents.

In addition, the chlorophyll analyses that have been made for some of the drainage streams (Tables 22, 31, 38, 45, and 64) were also unsuggestive of any water quality difficulties for surface water-public supply since the concentrations of this constituent in these waters were well below the levels that are indicative of stream eutrophy and the municipal-use problems that are known to stem from this condition. Even the high-nutrient East Poplar River had chlorophyll concentrations below those levels that would commonly point to eutrophic conditions. The pesticides were also unsuggestive of any potential municipal use degradations with the concentrations of these contaminants in those streams that were assessed in this manner (Tables 22, 45, and 64) well beneath the maximum primary drinking water regulation established by the Environmental Protection Agency for these organics, i.e., endrin at 0.2 ug/l (113). The maximum pesticide concentration observed for the Poplar streams was found to be 2,4-D at 0.02 ug/l, and this particular pesticide concentration was also far below the reference criteria for this constituent at 100 ug/l. For the most part, therefore, the various trace elements as group should not prevent the successful use of the Poplar Basin streams for public supply; only the phenols might tend to degrade their aesthetic values for this water use to some extent.

Recreation and Aesthetics

General considerations.

Recreation is generally considered to be one of the major uses of water in Montana streams even though the importance of this type of water use is often difficult to categorize in an economic sense. As a result and apart from economic reasons, some attention should also be given to the quality of a water that is being inventoried in a review in terms of its suitability for these kinds of pursuits, as well as its suitability for the more obviously economic ventures such as irrigation and stock water. This reasoning, in turn, can also be applied to the Poplar River Basin, although this particular region of Montana is not commonly viewed as a recreational paradise. Recreation per se is not easily defined, but considerations in this regard should also encompass aesthetic appreciations and leisure activities in addition to the more commonly accepted physical derivations of these pursuits such as various forms of boating and water skiing, swimming, hiking, fishing and hunting, and so on. Some thought, therefore, should be given to the recreational value of a water not only in relation to these physical enjoyments, but also in terms of wildlife maintenance and the water's aesthetic attributes since "aesthetically pleasing waters add to the quality of human experience (24)." Thus, some brief deliberations of the aesthetic status of the study area's streams will also be included in this report.

In the case of the Poplar Basin, recreational and fisheries pressures are comparatively small because of the low population densities of the area (49, 50), and this feature is advantageous to the region by avoiding excessive abuses of its recreational carrying capacity which in turn helps to maintain the basin's inherent aesthetic qualities. In addition, the Poplar drainage does not provide what might be termed a "classical scenic area" in the sense of the upper Yellowstone River drainage, for example, and this factor plus the basin's low recreational use might cause a reviewer to ignore the recreational capacities of the area and its unique aesthetic qualities. This would be unfortunate since the Poplar region does have recreational and aesthetic attributes that merit attention, and these features could be adversely affected to some degree by the power generation development near Coronach, Saskatchewan.

Fishing affords one of the primary recreational uses of a water, and the opportunity to cast into a healthy stream provides one of the major benefits for having such a stream in the close vicinity of any particular locale. The Poplar River Basin appears to be fortunate in this regard since on the basis of the available water quality and discharge data, most of the major streams in the region should afford a good to excellent, freshwater sport fishery. The only exceptions to this observation are probably located in the extreme upper segments of the streams near their headwaters areas because of the low volumes of flow that are found at these upstream locations.

But unfortunately, fishing in the minds of many Montana residents is synonomous with the cold waters that are found in close association with mountainous regions, and fisherman, thereby, often flock to these kinds of areas to the exclusion of other types of fishing opportunities. For example, the prairie natures of the Poplar streams obviously do not coincide with this image, which may account, in part, for their reduced recreational use, and

these particular waters because of their relatively high warm weather temperatures are most likely to have a warm water fishery over the cold water form, particularly in the lower segments of the drainage, although the upper reaches in or near Canada may be supportive of marginally propagating or stocked cold water species. Nevertheless, a viable and healthy warm water fishery in a prairie region, like the mountainous cold water form, also has its own awards and values that stand on their own right, and this occurrence, though often overlooked by fisherman, provides a valuable recreational resource to those areas that are fortunate enough to have such streams. These warmer prairie waters, therefore, are also certainly deserving of attention for preservation and perpetuation in the face of outside perturbations, and this appears to be the case for the Poplar drainage streams in view of the Coronach development, although the results of various fishery surveys now being conducted in the study region, and those recently completed (50, 69), will have to be assessed in order to definitely define the quality, quantity, and type of fishery that is characteristic of the Poplar Basin.

It might be assumed that the study region also has its particular forms of terrestial wildlife such as birds and mammals that inhabit parts of the drainage and utilize its water resources to some extent, and like the fishery, these features also merit some consideration from a preservational, aesthetic, and recreational point of view. As pointed out by the Environmental Studies Board (1973), in " . . . many instances, criteria to protect fish and invertebrates or to provide water suitable for consumption by man or domestic animals will also provide the minimal requisites for some species of wildlife. This would be (primarily) true for species that use water only for direct consumption or that feed on aquatic organisms to only a minor extent." The discussion presented previously in the "Stock Water" section of this report generally describes an excellent quality of water in the streams for domestic animals, and with reference to the Environmental Studies Board observation (24), this feature, thereby, should also describe a generally good quality of water in the basin for wildlife watering purposes. Specific water quality parameters that might affect the wildlife of a region will be discussed more fully in relation to the waters of the study area in the next sections of this review.

In association with these concerns for maintaining wildlife and fisheries habitat, the American people have also become increasingly cognizant of the aesthetic status of their surrounding environments, including the quality of their streams, and this awareness has been reflected in the continuing public demand for a "cleaner" water which was culminated in the establishment of various "208", areawide waste treatment management efforts throughout the nation and Montana in accord with Public Law 92-500. The Environmental Studies Board (1973) points out that the " . . . recognition, identification, and protection of the aesthetic qualities of water should be an objective of all water quality management programs . . . . Paradoxically, the values that aesthetically pleasing water provide are most urgently needed where pollution problems are most serious as in urban areas . . . where population and industry are likely to be concentrated (24)." From an aesthetic standpoint, therefore, the Poplar Basin is fortunate in having a low population density.

In recognition of the recent demand for aesthetic quality, the National Technical Advisory Committee (1968) developed a set of general water quality recommendations for aesthetic purposes that were largely reaffirmed by the

Environmental Studies Board (1973) in their subsequent Water Quality Criteria handbook. One of the major NTAC recommendations in this regard was stated as follows: "All surface waters should contribute to the support of life forms of aesthetic values (48)." As suggested by the previous discussions of this report, the quality of water in the Poplar River Basin apparently coincides with this recommendation, and this points to the superior aesthetic status of the drainage streams. In general, the drainage waters also correspond aesthetically to the other recommendations of this kind that have been put forth by the NTAC, and these features add confirmation to fact of high aesthetic qualities in the Poplar Basin streams.

The additional recommendations developed by the NTAC (1968), describing those factors that would lower the aesthetic values of a water, are listed below.

> Surface waters should be free of substances attributable to discharges or waste as follows:
> (a) Materials that will settle to form objectionable deposits.
> (b) Floating debris, oil, scum, and other matter.
> (c) Substances producing objectionable color, odor, taste, or turbidity.
> (d) Materials . . . in concentrations or combinations which are toxic or which produce undesirable physiological responses in human, fish and other animal life, and plants.
> (e) Substances or conditions or combinations thereof in concentrations which produce undesirable aquatic life (48).
>
> Substances and conditions referred to in (e), above, would include factors such as excessive nutrients and temperature elevation. Undesirable aquatic life would include objectionable abundance of organisms such as a bloom of blue-green algae . . . (48).

Many of these same factors have also been elucidated in Montana's Water Quality Standards (44).

With reference to the (a) and (b) recommendations of the NTAC (1968), various surveys of the Poplar drainage did not demonstrate the development of settleable materials and "objectionable deposits" in the streams nor the occurrence of "floating debris, oil, scum, and other matter" that would degrade the aesthetic attributes of the water. With respect to point (c), the color and turbidity levels of the streams were generally quite low and non-suggestive of marked aesthetic degradations. The only exceptions of this kind occurred primarily during the runoff periods of the basin which were quite short-lived in relation to an entire year. In addition, no objectional odors were specifically noted for the streams or their water samples, although the high phenol levels of some of the collections might be suggestive of some problems along this line, particularly after chlorination. However, these phenols were most likely derived from natural sources instead of being "attributable to discharges or wastes." The phenols could also afford some taste problems, and the dissolved solids values of the streams and the

concentrations of some of the common constituents were also at adequate levels to impart some degree of taste to the waters which could be objectionable if these streams should happen to be used for public supply.

In terms of recommendations (d) and (e), the previous discussions of this report indicate that severe toxicities and adverse physiological effects in humans (outside of the possibility of some mild laxative actions in some people because of the high dissolved solids and common constituent concentrations, e.g., sulfate) as well as in stock animals and terrestial and aquatic wildlife, along with the development of "undesirable aquatic life" because of high temperature and/or high nutrient levels, would not be generally expected for the Poplar Basin streams as a result of their water quality characteristics. In the main, therefore, the Poplar drainage waters might be graded as being aesthetically pleasing for most forms of human endeavor and recreational use at the present time.

Parameter-specific considerations.

Flow is an important variable to consider in terms of the recreational use of a stream since adequate volumes of water are necessary to allow for the appropriate pursuits of this kind, such as boating and swimming, and also to provide for the maintenance of the desired aquatic biota, such as a viable freshwater fishery for angling purposes. Adequate flows could be a problem in the Poplar streams, particularly in their upper reaches, because of the low discharges that are often found in these segments, and this aspect is greatly accentuated in some years, as experienced during the "dust bowl" era of the thirty's, because of the wide fluctuations in annual flow that have been observed to occur in the basin between wet and dry years (55). However, such problems probably have a natural, climatic derivation, and man's current influences on stream discharge appear to be relatively small since consumptive water uses in the region represent only a small percentage of the average annual flow of the streams at the present time.

But these man-related effects on the water resources of the basin could be enhanced to a marked degree through any further large increases of water consumption as will no doubt occur in association with the water demands of the Coronach power generating facilities, and this occurrence could have significant recreational-fishery implications for the region, at least with respect to the East Poplar River and possibly for the Poplar River mainstem above Bredette. As indicated by Needham (1976), the " . . . low, stable flows proposed for the East Fork will drastically alter the natural flow regimen of the river. It is anticipated that this condition will greatly impair walleye reproduction and contribute to channel eutrophication (50)." As a result, an equitable water apportionment decision between the United States and Canada will be very important in relation to preserving the fishery capacities of the East Poplar River.

The temperature of a water, like flow, can also restrict various forms of primary contact recreation such as swimming, diving, and wading. As recommended by the NTAC (1968), water temperatures for these particular pursuits should not be greater than 85F (30C) because of the potential for adverse physiological effects in the swimmers, particularly in association with extreme physical exertion. In turn, the Environmental Studies Board (1973) points out that waters with temperatures less than 59F (15C) may cause the

death of some swimmers while being extremely stressful to almost all of the people that enter the water. The upper temperature limit should have no application to recreation in the Poplar streams since their temperatures were consistently well below the 30C level (Tables 18, 40, 47, and 57), but the lower temperature limit would obviously restrict the use of the basin's waters for primary contact recreation through a large part of the year when the temperatures of the streams were well below the 15C value, typically from mid-September to about the middle of May (77, 91). Thus, the study area streams would be unsuited for some types of recreation through this span because of the cold waters that are found in the region at these times.

In addition, temperature can also have marked effects on the aquatic biota of a water including its fishery component. In the case of the Poplar drainage streams, the temperature characteristics of the region should not restrict the development of a viable fishery, but this water quality variable certainly does delimit to some degree the type of fishery and the form of fishing pleasure that might be found in the study area as follows: the probable elimination of a non-marginal, cold water fishery from the drainage because of these species' sensitivity to the relatively high summer temperatures that develop in the waters, and a delimitation of the warm water species that might inhabit the region by eliminating those forms that are sensitive to the markedly low winter temperatures of the waters (at or near freezing). However, the warm summer temperatures of the streams, which probably eliminates the development of a resident cold water fishery in the drainage, were not at adequate levels to be suggestive of the "temperature elevations" described by the NTAC (1968) that could enhance stream eutrophication and thereby cause aesthetic degradations of this kind. Rather, the low winter and relatively high summer temperatures characteristic of the drainage courses were most likely a natural phenomenon related to the basin's climatic characteristics and not affected to any marked degree by man's activities. In the main, therefore, the most successful fishing in the Poplar region is probably tied to the warm water forms for natural reasons. But this does not suggest that the basin streams are aesthetically and recreationally depauperate because of this fact.

Organic pollution does not appear to aesthetically degrade the waters of the Poplar Basin to any significant degree as illustrated by the low BOD, COD, and TOC concentrations and by the relatively low combined nitrogen levels of the stream samples. The high dissolved oxygen concentrations of the streams with their percent saturation values typically near 100% through most of the year also confirm this conclusion, and the low coliform levels of the drainage collections indicate an absence of large municipal effluents entering the basin courses. But DO levels were found to be distinctively low on a few occasions during the winter season in the upstream reaches of the region, but instead of pollutive influences, this feature was most likely related to the natural oxygen demand of the streams in the face of an inadequate re-oxygenation because of the thick ice cover that forms on the streams during this cold weather period. Such low winter DO's are suggestive of some forced sport fish emigrations out of these upper reaches, although this would not be a factor in the downstream segments, and for the most part, DO's in all of the Poplar waters, even during most of the November-February span, were well above the 5.0 mg/l lower limit recommended by Salvato (1958) as necessary for the maintenance game fish reproduction. However, if a poor fishery is detected in the upper segments of the Poplar streams, such as the East

Poplar River above Scobey (Tables 17 and 28), then the low DO's of the winter season at these sites might be viewed as a contributing factor.

The coliform levels of the study area streams were well below the NTAC (1968) recommendation for secondary contact recreation at 2000 fecal coliforms (FC) per 100 ml. "Secondary contact sports include those in which contact with the water is either incidental or accidental, and the probability of ingesting appreciable quantities of water is minimal (48)." Thus, the Poplar streams should be suitable on this basis for such recreational pursuits as various forms of boating, if appropriate, fishing, and incidental shoreline activities. But more stringent coliform requirements have been established for the primary contact sports such as wading and dabbling by children, swimming, and diving since the probability of ingesting pathogenic organisms are much greater in these instances. For these pursuits, the log mean fecal coliform level of a water should not exceed 200 FC per 100 ml and only 10% of the samples taken from the water should demonstrate fecal counts in excess of 400 per 100 ml (48). Calculations for the Poplar Basin surface waters showed a mean FC concentration for all of the streams at 47 to 58 colonies per 100 ml, and only 5% of the collections had FC counts greater than the 400 per 100 ml value. Thus, the Poplar streams, on the basis of their bacterial qualities, should also be suitable for the various forms of primary contact recreation listed above.

However, the pH characteristics of the study area waters might delimit the swimming and diving aspects of these contact pursuits to some extent. As noted by the Environmental Studies Board: "For most bathing and swimming waters, eye irritation is minimized and recreational enjoyment enhanced by maintaining the pH within the range of 6.5 and 8.3 except for those waters with a low buffer capacity where a range of pH between 5.0 and 9.0 may be tolerated (24)." In the case of the Poplar streams, these lower limits of pH should be of no consequence with this variable well above the 5.0 or 6.5 values. But these streams do have markedly high total alkalinity and bicarbonate concentrations with a large buffering capacity, and the pH's of the waters were consistently above the 8.3 level through that part of the year when the streams might be utilized for contact water sports because of the temperature factor. This feature, in turn, apparently lowers the recreational worth of the drainage waters by potentially causing eye irritations in the case of any extensive use of the streams for swimming purposes.

As described previously, the turbidity and color levels of the Poplar drainage streams do not appear to degrade their aesthetic qualities to any significant extent in a visual sense, and as a consequence of this factor, these waters would be expected to have a high degree of clarity in most instances because of their generally low suspended sediment concentrations. In addition to the aesthetic aspects, clarity is also important from a recreational point of view since the "safety and enhancement of . . . (recreational) enjoyment is fostered when the clarity of the water in designated bathing or swimming areas allows the detection of subsurface hazards or submerged bodies (24)." As a result, sufficient clarity is important to allow for an adequate light penetration into the water, and this feature also enhances the production of aquatic foods which are necessary to sustain the varions forms of lotic-lentic and terrestial wildlife that might be using the waters. Such positive features apparently apply to the study region streams because of their generally low color and turbidity characteristics,

and waters of this kind with high aesthetic qualities should also be suitable for most forms of boating activities (24) under the assumption that these pursuits are feasible in any region such as the Poplar Basin given the associated water volume-surface area and carrying capacity constraints.

From an "outdoor-use" standpoint, many of the water quality parameters, such as the dissolved solids and common constituents, should not directly degrade the aesthetic or recreational status of a water unless they are in such high concentrations as to be toxic or to cause physiological distress in the aquatic and terrestial wildlife using the water or in those people enjoying the water but who inadvertently experienced an accidental ingestion. The previous discussions of this report indicate that such problems would not be anticipated for the study region with respect to its dissolved solids and common constituent levels, e.g., carbon dioxide, bicarbonate, sulfate, sodium, and potassium, and this conclusion should also apply to many of the other water quality variables analyzed for the stream samples such as fluoride, silica, boron, iron, and the other metals and trace elements summarized in the "metals and miscellaneous constituents" tables of this inventory. Thus the waters of the Poplar drainage might also be graded as having an excellent recreational and aesthetic status on these particular bases. In addition, the pH values of the study area streams, although undesirable for swimming purposes, were well within the 7.0 to 9.2 range where aquatic plants that have the greatest value for waterfowl food show their highest levels of productivity, and the high total alkalinities of these waters should in turn insure a high level of primary production from these desirable plants since this occurs when bicarbonate concentrations are found above the 30 mg/l level (24) as has been observed for the Poplar area. These latter features, therefore, should also enhance the "outdoors" quality of the basin streams.

From an "indoor-use" standpoint, however, several of the water quality variables assessed for the basin streams could be suggestive of some mild aesthetic degradations, although these again would not be related to toxicities or to severe health factors. Rather, the dissolved solids and some of the common constituents, along with the phenols, appeared to be at adequate levels in the Poplar waters to impart some degree of taste to a drinking water, and odor in the case of the latter variable, and these features might be considered as aesthetically displeasing if the streams are to be eventually used as a source of water for public supply. In addition, the possibility of a mild laxative action in some of the sensitive people that might be consuming these moderately high DS waters would certainly be viewed as an aesthetic degradation by those individuals who happened to be temporarily afflicted in this manner. The high calcium, magnesium, and total hardness concentrations of the drainage streams should also lower their aesthetic worth by reducing domestic-use efficiencies, as has been described previously, and by causing the formation of encrustations on cooking utensils and other materials. But except for these particular variables, none of the other water quality parameters assessed for the study region would be expected to detract significantly from the "indoors" uses of the area's waters in these particular ways. That is, the metals and other trace elements did not appear to be at sufficient concentrations to impair the taste of the water or to cause any staining problems in laundering applications. With only a few minor exceptions, therefore, possible aesthetic degradations relative to these kinds of water uses from the Poplar streams would seem to be relatively mild and possibly eliminated through various forms of water treatment.

As a final consideration, the development of eutrophic conditions in a stream or lake is an undesirable occurrence relative to maintenance of these water's aesthetic and recreational values. The several aesthetically-related and recreational problems that can result from eutrophy have been generally summarized by the Environmental Studies Board (1973), and these can be listed as follows: the production of extensive littoral and emergent vegetation and aquatic weeds which provide harborage for various nuisance organisms such as mosquitoes and midges while interfering with the water's boating, fishing, and swimming activities while also closing a ready access to the water's shoreline; and the production of unsightly algal growths which can produce disagreeable odors, water discolorations and clarity losses plus the domination of unfavorable slime organisms such as Cladophora, Ulva, and Sphaerotilus. Other problems that could ultimately stem from the development of such "undesirable aquatic life (48)" would include the occurrence of tastes in a water plus the potential for toxic algal by-products and poisonings, oxygen depletions and its associated fish kills and odors, and the water use and water treatment difficulties that are related to filter clogging and lime formations plus the occurrence of biotically-induced water quality alterations such as increases in pH, decreases in alkalinity and total hardness, and increases or decreases in the oxygen levels of a water. Some of these latter features have been observed to occur in the Poplar streams on a seasonal basis. In addition, eutrophication often upsets in the natural flora and fauna of an aquatic system with undesirable shifts becoming evident in the species composition of its biotic communities. As a result, eutrophic streams and lakes possessing these adverse attributes would certainly be unpleasant from an aesthetic point of view.

In relation to most of the Poplar Basin streams, however, problems of this type would be unexpected with their waters most likely non-eutrophic because of the distinct nitrogen limitations that were observed to occur in most of these instances. But it should be noted for impact purposes that phosphorous concentrations were at adequately high levels in many of the streams to produce eutrophic conditions if the inorganic nitrogen concentrations of these waters happened to be elevated to appropriate levels because of some unspecified factors. The major exception in the drainage to probable non-eutrophy was found to reside in the East Poplar River above Scobey which had both its nitrogen and phosphorous nutrients at adequately high concentrations to be at least suggestive of the possibility for stream eutrophication even though the chlorophyll data that had been collected from these waters were at insufficient levels to point to the occurrence of severe algal blooms. Yet a dense aquatic macrophyte community has been reported for the upper East Poplar, and this observation may have been related to this segment's high dual nutrient concentrations. In this case, a large part of the stream's primary production would have been tied-up in this type of vegetation over the algal forms, although this has to assume the amenability of various other ecological factors in terms of allowing for the occurrence of extensive macrophytic growths. Such macrophyte communities, although beneficial on the one hand for aquatic habitat and food purposes, are actually undesirable aesthetically when found in too luxurious of a condition, as has been noted above. Thus, the macrophytes of the upper East Poplar could conceivably lower the recreational value of this one stream to some extent. But outside of the possibility for this one nutrient-related, aesthetic degradation, the remaining Poplar Basin streams and reaches would appear to be unaffected from stream eutrophication. As a result of this feature, they should also be aestheti-

cally pleasing because of the general absence of the kinds of problems that can occur upon the development of this unfavorable condition, in addition to having a high aesthetic status for the various other reasons that have been summarized earlier in this report.

SUMMARY OF IMPACT-IMPORTANT WATER QUALITY PARAMETERS

GENERAL ASPECTS

One of the major objectives of this study, in addition to providing a general water quality inventory of the Poplar River Basin in northeastern Montana, was the identification of those water quality parameters that were at critical concentrations in the study area streams relative to the current beneficial uses of these waters including recreational-aesthetic and instream aspects. It then might be assumed that these particular variables will be the most severely affected in terms of an appropriate water use feature in the case of any major water quality disturbances in the drainage, and such alterations in the concentrations of these critical water quality variables would be expected, thereby, to lower the quality and value of the streams' waters for these applications. The main points of concern for such disturbances or water quality impacts that are facing the study region at the present time reside in the coal-fired, power generation facilities that are now under construction near Coronach, Saskatchewan by the Saskatchewan Power Corporation (60). However, the water quality assessments that have been developed through this investigation should also apply to other potential impact sources such as expanded irrigation or various mining ventures, and they might possibly be of value in any deliberations dealing with potential changes in the water-use patterns of the drainage.

Through the previous discussions of this report, critical parameters of this kind in the Poplar Basin surface waters have been identified by referring stream concentration data to various water quality reference criteria that have been established through other research efforts to elucidate those levels of a variable where some degradations might be anticipated for a water application such as irrigation, stock animal watering, municipal supply, and drinking water. This same approach was also utilized with reference to various instream features such as the Poplar fishery and general quality descriptions. In addition, estimates were also made of the magnitude of parametric concentrational increases that would be required in the drainage streams to significantly reduce the efficiency of a water use or to totally negate a stream's suitability for any particular application. But beyond this effort, this study was not intended to specifically predict, quantify, or describe in detail the particular water quality impacts that might be eventually impinging upon the region, and it was not designed to elaborate upon the specific impact sources associated with the Coronach development, such as the concentrating effects of the reservoir and flow-through cooling, ashpond seepage, and spoils drainage, that might be producing the quality alterations. It is assumed that the water quality modelling endeavors and numerous other studies currently being conducted in the region will adequately address these more refined aspects of the overall problem.

Hopefully, the background-type of information that has been supplied by this particular investigation of the Montana Water Quality Bureau will nicely compliment the water quality modelling efforts now being conducted by this same agency. It is hoped that the results of these two separate studies will blend to form a comprehensive picture of the water quality inconveniences that the residents of the Poplar Basin have to experience at the present time, and some insight into the types of water quality difficulties that will have to be lived-with or resolved in the coming years because of developmental activities in the region. The point of the "Summary" chapter of this review is to briefly enumerate those water quality parameters that appear to be potentially critical to the present and future water uses and instream values of the Poplar drainage; more detailed and supporting information in this regard is available in the various sections of the main body of this report.

SURVEY OF CRITICAL PARAMETERS

This particular water quality inventory of the Poplar drainage streams revealed numerous water quality parameters that are potentially important in relation to the current water-use practices of the region and with respect to the instream status of its waters. In turn, many of the water-use problems associated with these variables could possibly be aggravated to varying degrees by impacts emanating from the Coronach facilities. But this review also showed that several of the parameters assessed for the region were at noncritical concentrations in this respect, and at the same time, many of these same variables would not be expected to be influenced by the power generation development to any marked extent.

Of the "field" parameters, BOD most obviously falls into this latter category because of its generally low concentrations in the Poplar drainage streams. This suggests that the study area waters were generally unaffected

by organic pollution with an inadequate oxygen demand to significantly lower the dissolved oxygen content of the streams much below 100% saturation. This contention is confirmed by the high dissolved oxygen and percent saturation levels of the waters, and the low DO's occasionally observed during the winter season were probably caused by natural features that are unique to this cold weather period rather than any pollutive influences. Similar to BOD, COD and TOC might also be graded as unimportant variables for these same reasons.

Fecal and total coliform concentrations were also unsuggestive of pollutive influences or water quality problems in the drainage since these bacteria were found at levels typically below Montana's Water Quality Standards (44) and below the reference criteria that have been established for surface water-public supply and contact recreation (24, 48). Water quality impacts expressed through the BOD, COD, TOC, and coliform variables, therefore, would be largely unexpected for the Coronach development unless an unforeseen and quite large influx of people should happen to occur into the region because of these facilities or for some other factor. Such population increases could produce an overloading of wastewater treatment systems and an increased discharge of organic materials and coliforms to the receiving waters. Although sufficient discharges of this kind to severely affect the streams would seem to be highly unlikely, this feature could be important during the winter season because of the tendency towards low oxygen concentrations in the upper reaches of the basin at this time that might conceivably cause forced fish emigrations, and this present problem could be enhanced by any further inputs of allochthonous organics into these particular stream segments during this season. But apart from this consideration, dissolved oxygen, like BOD, might also be viewed as a noncritical water quality variable in the surface waters of the study area.

Color, turbidity, and suspended sediment also appear to be noncritical water quality parameters in the drainage streams throughout a large part of the year because of their generally low concentrations. This observation probably excludes only the brief runoff period during the spring season. As a result, these three variables would not be expected to adversely affect any of the beneficial uses of surface waters in the region, including municipal supply, and these parameters were not at adequate levels to impair the aquatic biota of the streams to any significant degree, including their fishery aspects. In turn, the potential impact sources associated with the Coronach facilities do seem to be properly predisposed to afford any aggravations of these constituent's concentrations in the Poplar waters, particularly in view of the downstream reservoir.

Several of the common constituents might also be viewed as unimportant parameters in the basin streams because of their low concentrations and, in some cases, because of their non-affecting characteristics, and this also applies to several of the other variables that have been assessed for the drainage. Carbon dioxide, carbonate, phenolphthalein alkalinity, and potassium can be listed for the first case while fluoride, silica, various pesticides, and chlorophyll might be listed in the second instance. Similar to the physical features, significant effects originating from the Coronach development in terms of these eight constituents would not be anticipated for the region. In addition, the combined nitrogen species, i.e., total nitrogen, total Kjeldahl nitrogen, and total organic nitrogen, which were at in-

adequate levels to point to organic pollution, might also be placed into this noncritical category even though their concentrations appeared to be somewhat high in the Poplar streams in relation to what might be expected from many natural waters.

Except for one facet of its water quality profile, chloride, which was also generally found to be in low concentrations in the drainage streams, might also be viewed as a noncritical variable in relation to the water quality characteristics of the Poplar region. The major exception was found to reside in the extreme lower reach of the Poplar River mainstem near the town of Poplar where chloride was at adequately high levels to contribute significantly to the "potential salinity" levels of this segment, and high "potential salinities", in turn, can degrade the value of a water for irrigation applications. In the upstream waters, however, the contribution of chloride to this derived, irrigational variable would be relatively small. As a result and outside of this one particular influence, this anion should not have any major effects on the various water applications of the drainage or on the aquatic biota of its streams.

Similar to the observation for the pesticides, most of the other trace elements that were analyzed for the basin, with the possible exceptions of mercury and the phenols, did not appear to be at adequate levels in the Poplar drainage streams to continuously influence the region's aquatic biota or to effect the various applications of water from these sources. Any influences of this kind from some of the trace elements would most likely be sporadic and non-continuous in nature since only an occasional water sample from the drainage demonstrated a trace element concentration (total recoverable or dissolved) in excess of an appropriate water use or biotic reference criterion; in all cases, the mean and median concentrations of an element were well below these same reference values. This same feature was also observed for mercury, although this metal seemed to have a greater frequency of reference violations than the other trace elements which is suggestive of a greater probability for water quality problems. In contrast, many of these constituents even had their maximum basin concentrations below the various criteria, and for some of these elements, reference values for the several water uses of the basin and the aquatic biota have not yet been established up to the present time. More detailed descriptions of this kind with reference to each of the trace elements are presented in the main body of this report, but in the main, these constituents as a group can probably be viewed either as noncritical or as non-affecting water quality parameters relative to the Poplar River Basin. Fairly complete listings of these types of variables are available in Tables 22 and 27 of this review.

For many of the trace elements, impact sources associated with the power generation development would not be expected to elevate their concentrations in the Poplar streams to adequate levels to be influential on the water uses and aquatic biota of the region. However, this observation can not be applied "across the board" since many of these constituents can have adverse effects in minute quantities requiring only small additions to the streams to produce some difficulties of this kind. Thus, some of the trace elements might be viewed as critical parameters in this respect, and it is hoped that the other studies being conducted in the drainage will be able to more clearly describe the actuality and severity of such potential problems in terms of the ash pond discharges, stack effluents, flow-through cooling, spoil

bank seepage, and other impact features of the Coronach facilities. Boron, because of its high concentrations in the basin waters, has one of the most obvious degradatory effects of the trace elements on the major water uses of the region through its adverse influence on irrigation, and any increases of boron in the study area streams would certainly be ill-advised for this agricultural application. But at the same time boron apparently lacks any negative effects on the aquatic biota or on the other water-use aspects of the basin. For mercury, the recommendation put forth by the Environmental Studies Board (1973) should also apply to the Poplar Basin; that is, no mercury should be added to the natural environment (24).

In contrast to many of the trace elements, most of the other water quality parameters that were assessed for the Poplar Basin, in addition to boron and mercury, but not discussed previously in this chapter were found to be at adequate levels in the drainage streams to degrade at least some of their water uses and features to some extent. But the magnitude of such adverse effects could vary to a significant degree depending upon the specific parameter and water use-feature under consideration and upon the particular stream and season being inventoried. These aspects have been described in some detail in the main chapters of this report. Based on these discussions, the water quality parameters that can be graded as critical in the Poplar streams, and the ones that will be most likely affected by the Coronach activities, can be listed as follows: several of the common constituents including dissolved solids-specific conductance (salinity), bicarbonate-total alkalinity-residual sodium carbonate, sulfate-potential salinity, calcium-magnesium-total hardness, and sodium-SAR-percent sodium, with these variables having their major affects on the irrigation and domestic use-public supply applications of the streams but with only minor influences anticipated for their aquatic biota and their stock watering values. This listing would also include the phenols primarily for aesthetic reasons in drinking water, ammonia in some stream reaches for biotic toxicity, eutrophication, and public supply-water treatment reasons, and phosphorus and nitrite-nitrate from a eutrophication standpoint. In addition, pH can also be viewed as a critical parameter since the high summer levels of this variable tended to lower the worth of the streams' water for most beneficial applications. Temperature might also be considered as a critical factor if the drainage waters are to be maintained as a cold water fishery.

As a result of the critical natures of the above listed water quality parameters under the present conditions of the Poplar drainage, any future increases in the concentrations or levels of these particular constituents might be expected to provide some degradations relative to the value of these streams for the various water-use applications of the basin. But this again would vary to a significant degree depending upon the parameter, the specific use of the water, and also upon the season of the year. The increase factors that will be required for any of the variables to degrade a particular water use or feature by season have been listed and discussed in the previous sections of this report, and the results of the water quality modelling efforts in the region, when available, should reveal if such concentrational elevations are feasible for the different locations of the basin in the relation to the potential water quality impacts associated with the Coronach development. As a general rule, it would appear that increases in the concentrations of many of these parameters on the order of two- to three-times in the streams should severely impact the quality of the basin's waters, and

preliminary considerations of the Coronach facilities (118, 119, 120) indicate that such large increases might be possible at the reservoir outflow of the development and therefore in the upper East Poplar River near the international boundary. This observation is suggestive of the possibility for some distinct water quality degradations in the study area that would be most pronounced in an up-drainage direction through the Poplar mainstem-East Poplar reaches and probably largely ameliorated through dilution by the time the impacted East Poplar waters arrive at the lower segment of the river near Poplar. Major effects of this kind will probably be demonstrated most obviously in relation to the irrigational values of the streams with somewhat smaller impacts anticipated in association with the other water uses of the drainage and its aquatic biota.

Flow might also be considered as a critical variable in the Poplar drainage that could be adversely influenced to some extent by the consumptive demands of the power generating facilities near Coronach, Saskatchewan, and such effects would also be most obviously felt in the East Poplar River and in the Poplar River mainstem immediately below Scobey. But since flow is not a water quality parameter per se, extensive considerations in this regard are probably beyond the scope of this particular inventory, although flow has been considered to a rudimentary level through the several sections of this report. A summary of the apportionment recommendation developed by the Poplar River Task Force (1976a) for the East Poplar River is presented in Appendix II along with some estimates describing the type of flows that the East Poplar might receive if this recommendation is put into effect. Such large reductions in flow on the order of 61% to 94% depending upon the magnitude of discharge in a water year would also be suggestive of some adverse influences on the water quality, water uses, and aquatic biota of this particular stream and the various downstream segments of the main river.

Prior to about 1970, the Poplar River Basin was an often ignored and sparsely populated agricultural region in northeastern Montana and Saskatchewan, Canada that contained primarily a prairie-type of stream with an unthreatened but largely marginal-type of water quality for the economically-related water uses of the region. However, these streams appeared to have a generally good quality to support the aquatic biota and wildlife that happened to inhabit the area including a viable freshwater fishery. As stated by Needham (1975), although " . . . Montana contains many prairie streams, few provide a sport fishery. While habitat in the Poplar River is now of sufficient quality to maintain a sport fishery, a narrow margin separates this river from numerous other streams which contain only nongame species. Any circumstances which would reduce water quality and quantity would in all probability result in unsuitable habitat for desirable game fish species (49)." With the advent of the proposal to construct a coal-fired, power generating facility on the East Poplar River near Coronach, Canada, the possibility for such quality and quantity disturbances in the drainage streams become greatly enhanced, and these impacts would have a special import to this particular region as a result of the marginal nature of its waters. A great deal of attention, therefore, is now being directed to this drainage by various agencies because of the potential that exists in the area for environmental problems, and hopefully some amenable decisions will be ultimately made on legal basis that will preserve the basin's water quality-quantity and thereby its biotic and beneficial-use characteristics through the coming years. It is hoped that this report will make a meaningful contribution to the successful resolution of the water quality impact problems that are facing the Poplar Basin at the present time.

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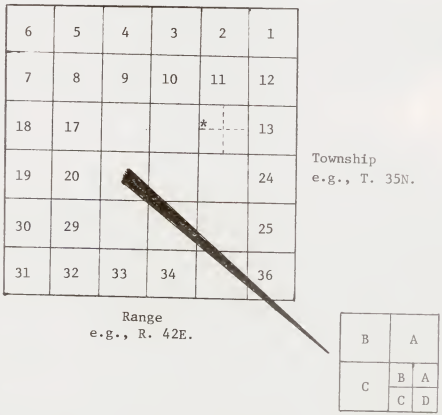
APPENDIX I. SYSTEM FOR THE GEOGRAPHIC LOCATION OF FEATURES

For this report, water-sampling locations and stream-gaging locations were assigned numbers based on the system of land subdivision used by the United States Bureau of Land Management. This designation consists of ten to thirteen characters and describes the location by township (north to south), range (east to west), section, and position within the section. The figure presented below illustrates the numbering method for the 36 sections contained within each township-range area. The first four characters of a location designation denote the station's township (e.g., T.35N), and the next four characters give its range (e.g., R.42E). The following two numbers give the location of the square-mile section containing the station (e.g., 14), and the subsequent letters, if present, describe the locations of quarter sections (a 160-acre area) and quarter-quarter sections (a 40-acre tract) within the 640-acre section (e.g., 14BC). The quarter-quarter-quarter section (a 10-acre tract containing the station) is also occasionally designated in a few of the geographic descriptions (e.g., 14BCD). As indicated below, these section subdivisions are labelled by the letters A, B, C, or D in a counterclockwise direction beginning with the northeast quadrant. Thus, the designation of 14BCD at the end of a description would indicate that this station is located someplace within the 10-acres of the southeast quarter (D) of the southwest quarter (C) of the northwest quarter (B) of section 14. Using the asterisk in the below figure as an example of a station location, its legal description would be listed as follows: T.35N, R.42E, 14BC. The United States Geological Survey (USGS), however, presents a somewhat different description for their sampling locations; for this same station, the USGS description would be given as follows: SW¼ NW¼ sec. 14, T.35N, R.42E.



APPENDIX II. ESTIMATES OF FLOW IN THE EAST POPLAR RIVER BASED ON THE APPORTIONMENT RECOMMENDATION DEVELOPED BY THE POPLAR RIVER TASK FORCE (1976a).

Natural Flow in the* Middle Fork (Acre Feet) (March 1 to May 31)	Percent Occurrence for the Years of Record*	Flows Delivered** to the East Poplar cfs	dates	Flow on** Demand (Acre Feet)	Total Flow Yearly (Acre Feet)	Estimated Percent of East Poplar Yearly Flow*
<3,800	20.4%	1.0	(6/1 to 5/31)	300	1024	>22%
3,800 to 7,500	25.0%	2.0 1.0	(6/1 to 8/31) (9/1 to 5/31)	500	1406	15% to 30%
7,500 to 12,000	25.0%	3.0 2.0	(6/1 to 8/31) (9/1 to 5/31)	500	2130	15% to 23%
>12,000	29.5%	3.0 2.0	(6/1 to 8/31) (9/1 to 5/31)	1000	2630	<18%
10,833	Average Year	3.0 2.0	(6/1 to 8/31) (9/1 to 5/31)	500	2130	17%
1,521	Minimum Year	1.0	(6/1 to 5/31)	300	1024	39%
43,222	Maximum Year	3.0 2.0	(6/1 to 8/31) (9/1 to 5/31)	1000	2630	6%

* Data obtained from the natural flow estimates of the Poplar River Task Force (1976c).
**Data obtained from the apportionment recommendation.